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# Strengthening Mathematics and Science Education in Africa [SMASE-AFRICA]

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**Strengthening Mathematics and Science Education in Africa**

# SMASE-AFRICA

## Journal for Science, Technology, Engineering and Mathematics Education in Africa (JSTEMEA)

## Table of Contents

# EDITORIAL BOARD

# PREFACE

## Welcome to the Third Edition of the Journal for Science, Technology, Engineering and Mathematics Education in Africa (JSTEMEA)!

The seventeenth Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA 17) international forum whose theme was, "*teacher professional development in Africa: developing knowledge, skills, and values in STEM teaching and learning engagements*" was held in December, 2019 in Nairobi – Kenya. Teacher professional development in Science, Technology, Engineering and Mathematics (STEM) education is a critical area of discussion owing to its importance in equipping learners for the 21st century lifestyle. Research in this area not only widens the scope of understanding the context of STEM education, but also deepens knowledge and skills that respond to the needs of the African continent.

In order to realize the fore-going, the international forum focused on five topical strands: (1) teacher professional development in Africa towards developing knowledge, skills, and values in STEM learning and teaching engagements; (2) role of professional associations in STEM teaching and learning; (3) school culture and learning in STEM towards creating supportive learning environments; (4) STEM curriculum development, implementation and assessment; and (5) ICT integration in STEM education. A total of thirty-eight papers were presented during the conference and some papers were rated highly by the scientific reviewers in terms relevance to the conference theme and aspirations of the continent. This 3rd edition of the journal therefore will continue to further trigger research in this crucial area of STEM education from early learning to tertiary levels of education. It contains thirty-eight (38) research papers that were presented during the forum.

The international forum was informative and stimulating with an array of keynote and invited speakers from Africa. The delegates had a wide range of sessions under the five strands to choose and learn. The program was well structured to include invited sessions, technical exhibitions and workshops on STEM lessons and discussions on a wide range of topics. The program was rich according the attendees an opportunity to meet and interact with one another.

This is to thank the organizing committee, members of the editorial committee and reviewers for the valuable input in the quality of papers and making suggestions to the authors. Gratitude goes to the external reviewers from other African countries who supported the review process and authors for contributing papers to the conference.

It is our hope that COMSTEDA 17 was an enjoyable learning experience and look forward to seeing more research papers in COMSTEDA 18.

**COMSTEDA 17 Organizing Committee**

# ABOUT SMASE-AFRICA AND COMSTEDA FORUMS

**SMASE-Africa Association**: The Strengthening of Mathematics and Science Education in Africa (SMASE-Africa) is a network of African countries started in the year 2001 as an initiative for addressing challenges facing mathematics and science education on the continent. SMASE-Africa is Pan-African Organization with a membership of 27 African countries. It is registered in Kenya under the Societies Act CAP 104 of the Laws of Kenya. The regional secretariat and headquarters are located in the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) in Nairobi, Kenya. The aim of the network is to create synergy in promoting dialogue on effective classroom practices in mathematics, science and technology education through research, fostering relevant policies, networking, collaboration, advocacy and capacity building in Africa.

**Vision:** *"A leading organization in promoting effective classroom practices for quality STEM education in Africa"*

**Mission**: "*To promote effective classroom practices in Science, Technology, Engineering and Mathematics education through research, fostering relevant policies, networking, collaboration, advocacy and capacity building in Africa*".

**COMSTEDA International Forums**: The Conference on Mathematics, Science and Technology Education in Africa (COMSTEDA) was launched in 2016 to capitalize on gains made under the SMASE-WECSA (2001-2014) regional conferences. It is a continental platform for educators to share innovative ideas, best practice, and interrogate issues relating to teaching and learning. The aim is to strengthen the capability of youth in Science, Technology, Engineering and Mathematics (STEM) subjects for 21st century living. COMSTEDA 17 was hosted by Kenya under the theme, "***Teacher professional development in Africa: knowledge, skills and values in STEM learning environments***". Educators, policy makers, researchers, teachers, NGOs, public and private sector stakeholders gathered to present papers, posters, exhibitions and workshop concepts.

The objectives of COMSTEDA 17 were:

1. To bring together educators, governments, academic and private sector institutions to interrogate issues, share ideas on best and promising practices and challenges relating to the teaching and learning Mathematics, Science and Technology Education in Africa
2. To improve quality of education in Africa through sharing impact and research findings on classroom practices to inform policy and practice
3. To present case studies and research findings in Mathematics, Science and Technology Education in Africa
4. To promote and highlight the role of STEM education in the development of the continent

# EDITORIAL

## Strand 1: Teacher Professional Development in Africa: Developing Knowledge, Skills, and Values in STEM learning/teaching engagements

*Article 1*

*Isabella. P. Ntsabane-Makgwatsana* sought to determine science trainee teachers' perceived knowledge gaps using Shulman (1987)'s categories of teacher professional knowledge. In the article, "**Science trainee teachers' perceived knowledge gaps during teaching practice: Case of Molepolole College of Education"**, engaged science trainee teachers during teaching practice in order to determine perceived knowledge gaps priori to post teaching practice. The findings indicated that the trainee teachers' perceived knowledge gaps were in the following areas: scheme of work, lesson introduction, lesson planning, assessment, teaching methods, teaching/learning aids, improvisation of laboratory equipment and handling of pupils with learning and behaviour problems. In light of the findings, the researcher recommended that the department of science should consider balancing contact time to mitigate the identified gaps during teaching practice.

*Article 2*

*Paul Waibochi* in the research on, "**Promoting continuous teacher professional development through school based INSET for sustainable development: The Dagoretti lesson study model approach"** examined the most effective professional development practices in teaching secondary school mathematics. The researcher pointed out that there are no well-established school-based teacher professional programmes in Kenya. The study implemented a pilot lesson study in Dagoretti region in Kenya to test a model that would strengthen school-based teacher professional development. The findings revealed that the model was successful and cost effective. The study recommended that the model can be replicated in other clusters, sub counties or regions of the country as well as other subjects other than Mathematics.

*Article 3*

*Dr. Ochieng' Obonyo* in the paper titled, "**Intergrated approaches in physics pedagogy; Active learning strategies in physics teaching"** stated that teaching and learning of physics requires a great paradigm shift to make it effective and therefore create a pool of creative physicists in future to drive the industrialisation agenda of the country. The study described strategies that can be adopted to help educators; build an integrated understanding of various elements of Physics Education Research (PER), including teachers' skills, reform-based curricula together with evidence of their effectiveness. The researcher recommended that the creation of scientific mind and skills should be the focus strategy and that Physics teachers should embrace project work and students' engagement in the learning process to make it successful and create a society with physicists who can drive the country's agenda of industrialisation.

*Article 4*

The article titled, "**The innovative teacher: A pinnacle of the 21st century learner-centred teaching of Biology"** by *Tawana Chaba Nancy* who sought to find out about ways to unravel the lack of passion and curiosity amongst learners. Study findings showed that the learner-centered approach increased the overall academic performance from 28 % to 36 % credit pass. Based on these findings, it was concluded that the learner-centered approach has an impact on the academic performance of the science double award Biology learners in a positive way. The study recommended that universities and colleges of education should include effective use of learner centred methods as part of professional development.

*Article 5*

*Shanah Mompoloki Suping* and *Onalenna Masi Sithole* in the article, "**Teacher professional development: Equipping science teachers with necessary constructivist classroom skills"** reported on a partnership between a science teacher and a science educator on a professional development activity. The study aimed at increasing opportunities for learning by students at every teaching episode. Two purposefully chosen classes were given different treatments on a topic at the junior secondary school level. One treatment was a constructivism learning environment while the other was a traditional teaching lesson. Results revealed that whilst the teacher was a qualified science teacher with many years of experience, the partnership with the science education specialist was fruitful. It was suggested that professional development activities need to pay more attention to teacher needs than perhaps the traditional route of paying more attention to student performance.

*Article 6*

In this article titled: **A survey on ICT Integration implementation: A case of schools in north east regional operations for education in Botswana**, Mr Mmoloki Dithebe and Dr Spar Mathews posit that the use of ICT in teaching-learning although critical, most regions have not yet embraced this initiative. They therefore evaluated the role of ICT integration as an initiative to enhance delivery in the classroom. The results from North East Region indicated that out of 160 participants from 13 schools, only 75 (46.9%) were trained on ICT integration. It was recommended that it is imperative to have enhanced capacity building and high speed internet connectivity to motivate implementation of ICT integration in teaching after training.

*Article 7*

*Alioni Luciano Cazu* in this article titled, "**Promising approaches in teacher professional development, the case of St. Mary's Ediofe girls' secondary school"** stated that there is a growing concern that teachers do not often undergo a total formation in a training institution. The study was designed to investigate if locally sanctioned scholarly strategies could supplement college training that teachers undertake, so that their performance improves. The study revealed that training institutions did not do enough to prepare the teachers because the teachers' preparation for teaching showed a huge variance in reference to STEM and teaching competency. The research findings indicated that teachers who could not fully embrace the strategies of teaching well either made poor teacher references or could not teach well. The study recommended that teacher networks and collaborations should be encouraged to fill observed gaps.

*Article 8*

*Lesley T. Kehitile* examined the implementation of evidence based research as a solution to STEM education reforms and reviewed the studies about its effects on teaching and learning in the study titled, "**Reinforcing evidence based research among lower-middle education level; A solution to STEM educational reforms".** The purpose of the study was to show how reinforcing evidence based research among lower-middle education STEM teachers remains the solution to repeated "sought after" STEM educational reforms. The paper identified that there is a low implementation of STEM education at lower-middle education. As such, nurturing of children's creativity and innovativeness is delayed until higher education. The author recommended that researchers should be supported when conducting evidence-based STEM education that produces reliable and generalizable results that will inform educational policy and empower future practitioners.

*Article 9*

*Mr. Kipkoech Kitur, Kitala and Mr. Wanyonyi S. Kisaka* in the article, "**Need for in service training towards strengthening innovative pedagogies, inclusive and quality education"** pointed out that there is need to promote promising approaches for effective teaching and learning. In this paper, the researchers advocated for strengthening inclusive and innovative pedagogies. The findings of this study revealed that there is a need to enhance 21$^{st}$ century skills/competencies, innovative and inclusive pedagogies. In light of this, the study recommended that the Ministry of Education and the Teachers Service Commission should focus and stregthen in-service trainings on these pedagogical approaches.

*Article 10*

*Tom Penlington and Fezeka Mkhwane* in the article, "**The Rhodes University mathematics education project in-service BEd and collegial cluster teacher professional development model"** stated that the lack of suitable and efficient professional development interventions in schools is prevalent. They reported on the professional development model designed to support and bring about changes in practice of mathematics in-service teachers while at the same time providing them with an accredited qualification from a university in the Eastern Cape of South Africa. The findings of the study indicated that teachers' views about the role of mathematics have changed.

*Article 11*

*Caroline Noel Amunga* questioned the role of religion in the contemporary era where science and technology have grown a large interest in educational systems. In the article titled, "**Intersection**

**of religion and science: The influence of Christian values on STEM"**, sought to establish the importance of Christian values on STEM. The study used exploratory approach to review documents and meta-synthesis. The findings revealed that science and religion are not at war, but are complementary for the realization of a better society. Therefore, it recommends that religious values need to be taught alongside STEM to achieve spiritual and psychological balance.

*Article 12*
*Mamocheta Makara* and *Nkoja Khechane* in the paper on, **"Effect of lesson study on students' performance: The case of secondary mathematics students in the rural-mountainous area in Lesotho"**, ran an analysis on the impact of Lesson Study (LS) on student's performance in mathematics in the rural area. Using mixed methods design, the study observed three mathematics teachers and a sample of grade 10 learners. The findings revealed that both learners' performance, teachers' content and pedagogical knowledge improved during the year in which LS was carried out. The paper recommended that LS be used in the teaching of mathematics especially in schools in rural areas.

*Article 13*
*Chako G. Chako* researched on what constituted a mathematics explanation. In the article titled**, "The constitution of a mathematics explanation in Botswana secondary schools"**, conducted a comparative study on how the same mathematical concept could be explained by different teachers. The purpose of this study was to have an insight of different or similar procedures teachers used to explain the same mathematical concepts. The findings demonstrated that post lesson plan was different from the pre-lesson plan and it was observed that both teachers and learners understood the lesson well after teacher had applied the concept of legitimization. The study recommended more exploration on what goes on inside mathematics lessons for policy and teacher professional development.

*Article 14*
In the article, "**An assessment of the application of ASEI-PDSI principles in Biology in Taita Taveta county, Kenya"**, *Roseline M. Osugo and Ephantus M. Kaugi* sought to evaluate the implementation of ASEI-PDSI principles in schools in Taita Taveta county, Kenya. The purpose was to study the influence of the SMASE INSET in the implementation of ASEI-PDSI and to distinguish the dominant ASEI-PDSI principles that were applied in teaching Biology. The findings pointed out that most teachers attended the SMASE INSET, but environmental, didactic and time issues made the application of ASEI-PDSI principles difficult. This study recommended the need to address misconceptions of teachers towards the INSET and the barriers to the application of the ASEI-PDSI principles for better performance in Biology.

*Article 15*

*Clemence Chikiwa and Bernard J. Ssennyomo* paper on, **“Visualization processes in conceptual teaching of word problems in grade 9 mathematics classes”**; assess the use of visualization strategies in the teaching of mathematics. The findings revealed teachers’ inability to build on prior knowledge rooted in everyday life. The study indicates that many teachers were not using visualization methods to teach mathematics. The paper recommended in-service programs and workshops to support teachers on how to optimally use visual tools and strategies in mathematics classes.

## Strand 2: Role of Professional Associations in STEM Teaching and Learning

*Article 16*

*Dr. Josephine N. Ojiambo and Stephen Wekesa Masinde* analyzed the, “**Influence of SMASSE on the quality of teaching and learning of mathematics and sciences in public secondary schools in Bungoma county, Kenya”**. The purpose of this paper was to determine the influence of SMASSE on the quality of teaching and learning of mathematics and sciences. The research findings indicated that teachers gave continual assignments to students for group discussion. ASEI-PDSI was used during lessons, and the school administration sponsored mathematics and sciences teacher using the SMASSE INSET and teachers encouraged students to present activities in class during mathematics and sciences lessons. The study recommended that the ministry of education need to equip schools with necessary teaching and learning resources to boost the quality of mathematics and science subjects.

*Article 17*

*Marjorie S K Batiibwe, Caroline Taliba, Betty K Nannyonga and Carla Puglia*, in the article titled, “**Exploring factors affecting students’ attitude towards mathematics: A case of Mayuge district in Uganda”**, sought to identify the reasons causing learner’s poor performance in mathematics. The research found out that students, teachers, social-economic status, the school as a learning environment, and the nature of mathematics were factors that affected students’ mathematics attitude. The article recommended further interventions from funding bodies with a focus on promoting STEM education in low-income countries.

*Article 18*

*Dr. Roselyn Marandu-Kareithi, David Jenkins and Daniel Hampton* reported **on, "Promoting entrepreneurial mindset development amongst high school learners in Kenya: A pilot project through partner organizations"** discussed the need to equip young people with entrepreneurial skills from an early age. This study conducted an online six-weeks experiential learning entrepreneurship challenge. Results show that learners have a high desire to develop their entrepreneurial thinking. It also confirms that collaborating with partners is a strategic means of rapidly reaching and providing this entrepreneurial mindset development opportunity to stimulate entrepreneurial thinking of as many learners as possible.

## Strand 3: School Culture and Learning in STEM

*Article 19*

*Tshepo Sharon Leepile Baipusi*, in the research on, "**Women in leadership, gender bias in ICT leadership in Botswana's Schools: The case of the central region"** studied the implication of women in leadership. The purpose of the study was to determine if gender bias existed in Botswana's schools. The study focused on gender imbalances in ICT leadership in schools. The findings indicated that only one quarter of people leading ICT departments were women. The study recommended adequate polices to promote women in ICT within Botswana's education sector.

*Article 20*

*Ms Olga Taolo* questioned: "**Is Botswana education system inclusive of learners with special educational needs? A case study of four junior secondary schools"**. The purpose of the study was to determine the inclusion of students with special needs in schools. Qualitative methods and a variety of sources were used to carry out the study to attest to the availability of provisions for special needs learners. The findings indicated that only a few teachers had special education qualifications and most did not vary methods during lessons, thus excluding those with special needs. The study recommended that the government need to provide infrastructure and resources, strengthen the capacity of supervisors to make sure that teachers employ relevant pedagogies to assist learners with disabilities, and educate parents & communities on inclusive education.

*Article 21*

*Dr. John N. Purdul* discussed the "**Influence of politicism on institutional leadership in public secondary schools in Kajiado county, Kenya".** The study investigated the strong connection between the public secondary schools and political institutions because politicians provide financial assistance, bursaries, infrastructural development and donations to schools. The paper pointed out that cultural, political and traditional influences continue to influence and dictate the nature, status and composition of leadership in public secondary schools in Kajiado County. The results of the investigation show that in many public secondary schools, political interests continue to supersede the interests of the schools. The researcher concluded that politics makes both positive and negative contributions towards the education sector and thereby recommending that political interference be either minimized or eradicated from public secondary schools in order to maintain a professional environment.

*Article 22*

*Peter Mureithi Ndiritu* on the research on, *"***School culture and learning in STEM: Creating space for in/out of school STEM learning and application",** described that the quality of teaching is the most critical in the school factor impacting on learners' outcome, facilitated by the learning culture of the school, individual teacher's pedagogical knowledge, skills and dispositions towards learning. Lack of effort for innovative teaching and learning strategies that are learner-centered has led to adoption of teacher-centered instructional approach to learning. The study analysed Kenya Certificate of Secondary Education (KCSE) examination grades for students in Mt. Kinangop girls secondary school in three STEM subjects (biology, chemistry, and physics). The research found a culture of teacher-centered approaches to learning that tend to discourage learner interaction. This practice inhibits effective learning of STEM subjects resulting in low skill acquisition. The study recommended the creation of a school culture where teachers use innovative teaching strategies to facilitate an inviting space that promotes effective learning, its application and acquisition of 21$^{st}$ century skills.

*Article 23*

*Harris Mwaniki Kariuki* in the paper, **"The formula for the image P (p, q) for the object A (a, b) in the mirror line y=mx +c",** states that the matrix method was widely used in obtaining the image of an object under reflection in the line y = mx + c with the mirror line almost always passing through the origin O (0,0). The paper highlighted that to obtain reflections where the mirror line does not necessarily pass through the origin O (0, 0), the rigorous process of substitution, elimination, simplification and verification must be employed. The findings of the study established that a simple formula linking the image point P (p, q) directly to the object point A (a, b) for a mirror line of gradient m and y-intercept c where c≠0, was very easy to work with as it gave more accurate results than those obtained by construction. This was useful where the matrix method of reflection is insufficient, and is applicable in all situations. The study recommended that there is need to extend the theory of reflection further to include reflection in a three-dimensional space. Thus, a formula for the image P (p, q, r) of the object A (a, b, c) in plane H would be obtained.

## Strand 4: STEM Curriculum Development Implementation and Assessment

*Article 24*

*Alfred Bhusumane* in the paper on, *"***Rhetoric and reality of postmodernism in mathematics education: The implementation versus performance in the Botswana General Certificate of Secondary Education Mathematics Curriculum"** stated that because of poor examination results, most of the mathematics curricula are focused on developing student knowledge through learners' discoveries and experiences during instructions. He pointed out that under the current mathematics syllabus, the learning approach is mainly teacher-centered. The results showed that a lack of learner-centered model of teaching mathematics contributes to poor performance in mathematics education. The paper recommended the adoption of approaches that are learner-focused.

*Article 25*

*Michael Gaotlhobogwe and Mojwadi L. Gosiame* in the research on, *"***Causal factors and impact of workplace injuries on teachers' performance: The case of design and technology in Botswana"** sought to determine and explain the factors that cause workplace related injuries and related impact on Design and Technology (D&T) teachers in Botswana. The source of data and the unit of analysis of the study were the documented reports of occupational accidents that occurred from 2014 to 2018 registered with the Botswana Sector of Educators Trade Union (BOSETU). The study found out that D&T activities presented the highest levels of risk and occurred during material preparation for students' practical projects. The injuries had a negative impact on those affected, from physical health to mental state as well as emotional well-being, which in turn disrupts learning. Most accidents occurred among teachers in the early years of their career. The study concluded that protection measures are inadequate and hence recommended that a raft of measures need to be adopted for instance; appointment of trained laboratory technicians and regular inspection of equipment to ensure the safety of both teachers and students.

*Article 26*

*Grace U. Onyebuch and Ify Evangel Obim* in the paper on, **"Facilitating STEM education for vulnerable school children through library outreach: The children centre linkages"** sought to uncover ways in which the school library enhances learning of STEM through the Children's Centre Library (CCL) in Nsukka, Nigeria. The study focused on two factors namely: the limited amount of time allocated to STEM in school timetables and the need to look at other learning environments other than the classroom setting in order to spark creativity in learners. The normal class surroundings and routines result in lack of creativity and innovativeness among children. A purposive sample of 10 professional librarians from a volunteer team of 23 university women was selected to participate in the interview study. The findings showed that the Children Centre Library had recognized the importance of school libraries to school activities; which have influenced the development of a reading culture and lifelong learning in the community. The paper recommended that schools fully integrate libraries in the timetable and all stakeholders work together in ensuring learning of STEM is effective.

*Article 27*

*Pelotlhomogi Modise* in the research on, **"Difficulty in syllabus objectives interpretation of junior certificate science syllabus"** described the importance of teachers in the implementation of the curriculum and their ability to interpret syllabus objectives effectively. The researcher explains that there are limited school based continuous professional development activities for teachers and this directly contributes to inefficiency in comprehension of the Science syllabus objectives. The study targeted integrated science teachers in junior secondary schools in Kgatleng Region, Botswana. Findings showed that there were no school-based continuous professional development activities to enable science teachers to formally collaborate on matters of effective classroom delivery and learner performance. The study recommended training of teachers on curriculum interpretation, decongestion of the current integrated science syllabus, leveraging on Information and Communication Technology (ICT) to promote 21$^{st}$ century learning.

*Article 28*

*Dr. Hafsat Lawal Kontagora and Ibrahim Sani* in the research on, "**An assessment of Strengthening Mathematics and Science Education- In-Service Education Training (SMASE INSET) on teacher effectiveness and pupils' participation and academic performance in mathematics and science education in Nigeria"** evaluated the impact of INSET on teachers of mathematics and science, stressing that a strong foundation in STEM was essential in a country's overall development. The study revealed that teachers using chalk and talk approach to teaching contributed to poor learning outcomes compared to the Activity-based, Student-centered, with Experiments and Improvisation through the Plan-Do-See-Improve (ASEI-PDSI) approach which was more effective. The study concluded that teachers who were trained and employed the ASEI-PDSI approach posted better examination results overall than those not trained. The study recommended the integration of ASEI-PDSI approach to the teaching and learning of STEM, frequent training of teachers and full government support.

*Article 29*

*Anthony Simiyu Mabele, Sarah Naliaka Likoko* in the study on, "**Modeling simulations on individualized learning in chemistry curriculum on students' achievement in Bungoma county, Kenya: structure and bonding"** proposed the modeling simulation approach as an effective way of teaching and learning of structure and bonding in chemistry towards student-centered learning. The study pointed out inadequate higher order thinking capability among chemistry students when handling the topic of structure and bonding. Reiterating the need to prepare learners for effective problem solving, thoughtful decision making and life-long learning processes. The researchers used two natural intact groups of students whose initial ability was based on school records, and assigned them to experimental (modeling) and control (no treatment) groups. The results of the study indicated that modeling simulations had a positive correlation with mean performance as compared to other traditional conventional lecture methods. The study recommended that chemistry teachers incorporate practical approach and use real life examples when teaching the topic of structure and bonding.

*Article 30*
*Nyokabi Njuguna* in the paper on, "**A review of the lessons learnt from learners through the implementation of the Experimento programme in low income public primary schools in Nairobi County, Kenya"** assessed the impact of the Experimento programme which employs the practical, discovery and learner-centered approach to STEM teaching and learning. The paper indicated that most education systems continentally were driven by systems set up in pre-independence Africa which took little consideration to context and indigenous knowledge issues leading to noticeable gaps in the education pathways. Siemens Stiftung, Impacting Youth Trust and Teachers Service Commission conducted an impact assessment analysis activity in July 2019 through the distribution of logbooks and field visits to 30 out of 90 schools that had benefitted from the Experimento programme. The findings indicated that the Experimento programme had influenced the delivery of STEM concepts to learners in the beneficiary schools. The paper recommended that education stakeholders need to make more investments in the adoption of practical-based approaches in STEM education.

*Article 31*
*Cyrus Muigai Kihara, Kevine Otieno and Loice R. Masese* in the article on, **"Colla-Petitive Strategy for collaborative learning environment in Schools"** posit that the current education system is faced with challenges of intense competition amongst learners where best performers are motivated by rewards, while those unable to compete are demoralized. This competition proved to be unhealthy. The researchers discussed collaborative learning pedagogy that enhances communication and collaboration among learners through intra-team collaboration and inter-team competition. This strategy proved to enhance teamwork and concern for one another to motivate all team members to performs better. The study revealed that schools that employ colla-petitive pedagogy have realized improved academic and disciplinary performance. According to this study, Colla-petitive pedagogy offers a unique opportunity to address the challenges of implementing the Competency Based Curriculum system.

*Article 32*
*Nkoja Khechane and Mamocheta Makara* questioned, **"Do primary teachers' assessment practices in Lesotho inform learners' learning of mathematics?"** This study sought to determine which assessment practices were visible in teaching of mathematics, and related effect on learners understanding. This study comprehensively discusses some of these assessment strategies. Results revealed that teachers were using strategies such as, sharing learning intentions, success criteria, peer and self-assessments which were helpful in learning of mathematics. The

authors recommend that teachers and learners need to be further trained on effective use of these strategies.

*Article 33*

*Kwaleyela Kwaleyela* investigated, **“Quantum mechanics symbology: How does it affect students’ understanding of introductory quantum mechanics concepts?”** The study pointed out that there are conceivable obstacles to learners’ understanding of introductory quantum mechanics arising from the symbols used. The author explores the challenges that students face in understanding introductory quantum mechanics, and discusses teaching strategies to be used to address the effects of symbolic obstacles. The research findings indicated that quantum mechanics symbology directly affected students’ understanding of introductory concepts. This study recommends that instructors need to allocate adequate time to explain the symbolism; employ conceptual models and teaching aids, procure updated and modern textbooks, and strengthen pedagogical issues in dealing with the abstract nature of the field and its symbolism.

## Strand 5: ICT Integration in STEM Education

*Article 34*

Skilling for the future (S4F) is a project in Uganda aimed at improving learning outcomes in mathematics through interactive, eLearning content. This research “**A digital content development concept using local teachers for effective integration of ICT in education”** by *Siima Gilbert Gift*, presents the methodology used to digitize Senior 1 Mathematics locally and the preliminary results from the trial of the digitized materials. The findings revealed that teachers not trained on computer programming lessons developed digital learning materials and only needed the right content authoring tools to get started. The author recommended scaling up of the project to more schools and subjects to support learning across the country.

*Article 35*

*Onesmus Gicheru* conducted a study on the **“Effects of Open Educational Resources (OERS) video explainers/graphic motion in a blended physics classroom”.** The study indicated that teachers spend a lot of time preparing for demonstrations and practical’s and hence the desire to conduct a research project that collects animated materials for physics related activities. The study used two groups, the experimental incorporated online OERS, and control used traditional lecture methods. The results showed that the esperimental group using OERS outperformed the other groups in all aspects. The researcher therefore recommended that graphic motion animations be integrated in the education system.

*Article 36*

*Moagedi Kereeditse and Tebogo V. Molebatsi* studied the, **“Use of various ICT tools in teaching and learning of Science”.** This research was carried out in Botswana, where the government has launched a number of initiatives to promote the use of ICT in teaching and learning. The study states that teachers’ motivation to use ICT in teaching and learning is adversely affected by a number of factors including; limited access to reliable resources, lack of confidence and experience with technology, lack of subject-specific guidance for integrating ICT in teaching and learning and effective use of ICTs. The findings revealed significant improvement in performance amongst students taught using ICT compared to counterparts not so exposed. On average, students who used ICT based instruction scored higher than those not so exposed thereby recommending the need to invest in ICT resources and facilities.

*Article 37*

**The paper on, “Challenges facing the implementation of NEPAD pilot e-schools’ initiative in Kenya”** by *Kennedy W Mumali* explored the level of expertise and skills possessed by teachers and students to utilize e-school ICT facilities, and the extent to which the e-school facilities were being accessed and used for classroom instruction during lessons. The research found a number of challenges facing effective implementation of NEPAD e-schools. One major challenge included lack of trained teachers in the field of ICT. As a result of poor teacher qualification in ICT integration, there was inadequate expertise and professionally skilled teachers to handle e-materials. The study also revealed poor accessibility to the few e-materials available in e-schools. The study recommended orientation of teachers in ICT and free accessibility to the e-materials.

*Article 38*

**Pupils’ attitude towards learning measurement concept: A case study of Ndii-ini primary school, Ruiru Sub-County, Kenya** by *Sheila.O. Amuko*. This study sought to find out the various attitudes experienced by pupils in the middle- upper primary while learning measurement concepts in Ndii-ini primary school in Ruiru Sub-county, Kenya. This study indicated that pupils come to school with a positive attitude towards mathematics subject. However, as they progress attitudes become less positive and frequently become negative by secondary school level. The findings revealed that students believe mathematics was a complicated subject and only geniuses can comprehend. The study further showed the learning environment as not conducive and lacked learning materials that enhance learning of measurement concepts. The study recommended further training of teachers on Competency-Based Curriculum.

**Strand 1# Teacher Professional Development in Africa: Developing Knowledge, Skills, and Values in STEM learning/teaching engagements**

1.School-based Teacher Professional Development: Policy, Strategies and Practices
2.Teacher Professional Development for Competency Based Education
3.Promising Approaches in Teacher Professional Development

**Article 1**

# Science trainee teachers' perceived knowledge gaps during teaching practice: Case of Molepolole College of Education

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## Abstract

The aim of this qualitative research was to collect science trainee teachers' perceived knowledge gaps. These gaps would be used to inform subsequent pedagogy lessons. A WhatsApp group, composed of thirteen (13) of the twenty-five (25) second year science trainee teachers, was used as a forum through which to collect trainee teachers' perceptions during teaching practice. Data was collected between 1st May 2019 and 11th July 2019. The researcher was an observer in the group chats. Data from group chats made this study novel because the voices of the trainee teachers were recorded in-situ. In-situ offered a live feed from the field, giving peer interactions in real time, which cannot be offered by the traditional survey after teaching practice period. Data was analysed using Shulman (1987)'s teacher professional knowledge categories. Specific perceived knowledge gaps were in scheme of work, lesson introduction, lesson planning, teaching methods, teaching/learning aids, improvisation of laboratory equipment and handling of pupils with learning and behaviour problems. The recommendations include exposing trainee teachers to school environment prior to teaching practice, the department of science to work more closely with school supervisors. Moreover, science lecturers should intensify support given to trainee teachers during teaching practice.

**Key words:** *trainee teachers; teaching practice; pedagogy; professional knowledge*

## Table of abbreviations

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| MCE | Molepolole College of Education |
| PCK | Pedagogical Content Knowledge |
| RNPE | Revised National Policy on Education |
| SDG | Sustainable Development Goal |
| UB | University of Botswana |

## Introduction

Botswana's education agenda is informed by two key documents: Education for Kagisano (1977) and Revised National Policy on Education (RNPE) (1994). A resounding theme in these documents is the critical role of education in driving the national economy. Education for Kagisano sought to bring an inclusive education system that promote social harmony and expand the skills base needed for national development (Republic of Botswana, 2008). On the other hand RNPE enabled for transition from a traditional agro-based economy to the industrial economy (Makwinja, 2017). To keep up with emerging challenges and a rapidly globalising world, Botswana had to transform her economy from industry-based mineral led economy into a knowledge society. This transformation was guided by Vision 2016 with a commitment to an informed and educated nation. Currently the country's transformation is informed by Vision 2036 which envisaged equal opportunities for all citizens in the education and skills development sector to effectively compete in a global economy (Government of Botswana, 2016). The second of the four pillars of vision 2036 addresses human and social development. It further outlines science as one to the subjects to be taught from primary to tertiary school level.

In Molepolole College of Education (MCE) science is offered as a teaching subject to those who aspire to be science teachers. These pre-service science teachers / trainee teachers are attached to schools for teaching practice. Teaching practice offers trainee teachers the opportunity to experience the real world context of teaching in order to develop professional teaching skills and competencies (Campbell & Kane, 1998). The professional teaching skills developed during teaching practice are important for effective content delivery once the trainee teachers graduate into science teachers.

## Statement of the problem

In an era of information technology, where information becomes obsolete quickly, feedback between teacher trainers and trainee teachers at teaching practice should be timeous. The two parties need continuous information flow between them in order to benefit most from the feedback from teaching practice. Improvement of teacher training and getting feedback from trainee teachers is vital in teacher professional development. The feedback from trainee teachers offers vital information that will inform subsequent teacher training decisions. In the end the college will produce highly competent teachers who would have had specific intervention strategies to address the gaps identified during teaching practice.

In a bid to continually inform teacher training practices, the college conducts annual surveys among trainee teachers returning from school-based teaching practice sessions. This is done at the beginning of an academic year, a month after the end of teaching practice. The time lag between teaching practice and survey creates a problem of losing out on some of the details of teaching practice experiences amongst trainee teachers. To off-set the impacts of time lag, college supervisors visit trainee teachers for assessment and get an indication of the knowledge gaps. However, this is inadequate because feedback is limited to performance during lesson time only. In addition, the feedback is from the college supervisor's perspective and does not take into account the trainee teachers needs as perceived by trainee teachers' 'eyes' and reported in trainee teachers' 'voices'. Getting feedback through surveys and from college supervisors have shortcomings that this current research hopes to avoid. Hence the purpose of this research is to engage science trainee teachers during teaching practice (to hear their voices during teaching practice and not post teaching practice). The study seeks to answer the question: What are the perceived knowledge gaps that science trainee teachers encounter during school based teaching practice sessions?

### Objective

1. Establish the science trainee teachers' perceived knowledge gaps encountered during school based teaching practice sessions.

This study is significant because it will be used to inform the researcher, who is also a teacher trainer in her subsequent methodology lessons. It will also help the trainee teachers because their identified knowledge gaps will be addressed by their lecturers and hence will prepare them better for final year teaching practice.

### Theoretical framework

The theoretical model informing this research is Shulman (1987)'s categories of teacher professional knowledge. These are: content knowledge, general pedagogical knowledge, curriculum knowledge, pedagogical content knowledge (PCK), knowledge of learners and their characteristics, knowledge of educational contexts and the knowledge of educational philosophies (Kind, 2009). Figure 1 shows Shulman (1987) model of categories of teachers' professional knowledge.


***Figure 1: Teacher professional knowledge according to Shulman (1987)***

**Source:** (Neumann, Kind, & Harms, 2018, p. 3)

1. Content knowledge refers to the amount and organisation of subject matter knowledge in the teacher's mind (Shulman, 1986). It requires going beyond definitions and explanations of science concepts. Content knowledge allows the teacher to justify the rationale for knowledge of science concept and being able to relate it to other concepts both within and outside of the science subject (Shulman, 1986).

2. General pedagogical knowledge is involved with all issues pertaining to student learning, classroom management, lesson planning and implementation, student assessment and student motivation (Mishra & Koehler, 2006). It is the 'how' of teaching developed through theory and teaching practice (Ngwaru, 2013).

3. Curriculum knowledge relates for programmes for teaching a subject, instructional materials that serve as tools of the trade for teachers (Shulman, 1986). These are items like syllabus, teaching methods, teaching and learning aids.

4. Pedagogical content knowledge refers to "knowing what teaching approaches fit the content, and likewise, knowing how elements of the content can be arranged for better teaching" (Mishra & Koehler, 2006, p. 1027). This is observable during lesson execution, when trainee teacher demonstrates the art of teaching. Since this research reports on trainee teacher reflections, PCK was not apparent.

5. Knowledge of learners and their characteristics refers to knowledge of the personal, academic, social/emotional and /or cognitive. Having this knowledge allows the teacher to design tailored instructions that is effective, efficient and motivating for the learners (Drachsler & Kirschner, 2011).

6. Knowledge of educational contexts, ranging from the workings of the group or classroom, the governance and financing of school districts, to the character of communities and cultures; and

7. Knowledge of educational ends, purposes, and values, and their philosophical and historical grounds.

The Shulman (1987) model is limited because it does not fully explain each type of knowledge, hence open to different interpretations. To its credit, the model has served as a start-off point for other researchers to conceptualise teacher knowledge.

## Personal Perspective

The participants in this research were students whom I taught at first year pedagogy course and they were aware that I was a member of their science *WhatsApp* group. My relationship with the participants is at a professional level. I would like to improve the quality of teacher preparation courses that the department of science offers. Related to that is the need to see the participants maturing into highly effective science teachers.

## Methodology

This qualitative study used a phenomenological approach. This approach explored the unique experiences of the participants as they were lived (Dell'Angelo, 2016), and data was collected at the time of teaching practice, not after. Collecting data *in-situ* offered a live feed from the field to the researcher, which was better than post teaching practice period when trainee teachers' perceptions would have been distorted by time, reflection and feedback from others. In addition, collecting data post teaching practice is artificial because participants have to recall from memory while group chats offered feedback as the experience was lived.

The population was Molepolole College of Education second year science trainee teachers. They were twenty-five (25) in number and those included in the sample population were those who were members of the science *WhatsApp* group. These were thirteen (13), making the sample size to be 52% of the population. These were attached in junior secondary schools in the southern part of Botswana. Each science trainee teacher had a mentor i.e. a school based science teacher who supervised them during the entire teaching practice period. Those members of the population who were not on the group were excluded from the sample. Data was collected between 1st May and 11th July 2019. A *WhatsApp* group, which had been used throughout the semester was used to observe what trainee teachers talked about during the teaching practice period. The comments were analysed weekly and common themes sought throughout the whole teaching practice period.

## Findings

To answer the question on knowledge gaps perceived by science trainee teachers during teaching practice, the following themes emerged: science content, scheme of work, lesson introduction, lesson planning, teaching methods, laboratory equipment, assessment, school mentors, pupil behaviour and comparison with University of Botswana.

**Content**

Discussions based on science content matter were on two topics only. These were amphibians and limewater preparation. On amphibians one trainee teacher asked for examples of amphibians and another helped her out. For limewater the discussion started with how to prepare limewater. The trainee teachers expressed lack of confidence on limewater preparation. The inquirer on the other hand expressed a rare but important teacher quality - tenacity. Following the discussion thread revealed a rare but important teacher quality – tenacity. The inquirer first tried out her carbon dioxide test prior to the lesson. When the limewater did not turn milky in the presence of carbon dioxide, she planned to prepare her own, hence the question.

**Scheme of work**

Comments on the scheme of work were two-fold. The first aspect was on general assistance in preparing the scheme of work. From the comments it was apparent that trainee teachers were not confident in preparing a science scheme of work, indicating a gap in the pedagogy courses offered at the Department of Science. Their comments indicated that they were better prepared to do mathematics scheme of work than science. Secondly, trainee teachers' scheme of work was different from the school mentors'. This difference shocked the trainee teachers because they had expected the school mentors' scheme of work to be better than theirs. One made a comment, stating "*Heela scheme sa batho kwano se tsaa only 2 pages!!!"* Loosely translated it means: The scheme of work here is two pages only! This observation of inadequate scheme was echoed by several trainee teachers in different schools. One cautioned that generally schools did not include pupil activity and learning material in the scheme of work. She further advised that they should *use the school scheme "as a guide",* and not to copy it*, "se ta le feidisa"* (you will fail your teaching practice if you copy it).

**Lesson introduction**

Questions and comments on lesson introduction were common from third week to the last week of teaching. Common questions were "how do I introduce…" "what previous knowledge do I assume when introducing…". These showed that the trainee teachers felt their knowledge on lesson introductions was not adequate. Such questions sparked fruitful discussions because other members of the group commented on the suggested lesson introductions.

**Lesson plan**

While some trainee teachers asked for assistance with specific aspects of lesson plans, others asked for complete lesson plans to plagiarise. Most wanted those who had taught the lesson before them to share their lesson plans. Though sharing of lesson plans is encouraged it also has the downside of encouraging laziness where one would just duplicate his/her colleagues' lesson plan without improving it. This request for lesson plans was common during the first weeks of teaching practice, because trainee teachers were still struggling to find their ground.

**Assessment**

One trainee teacher was appalled by the absence of assessment in the school. He commented that "teachers here do not apply themselves…no quizzes'. This trainee teacher had expected school supervisor to assess each and every lesson as he has been taught at college. However, this was not the case on the ground. In contrast, assessment in some schools was the norm. Some even had weekly science remedial lessons. A positive lesson out of the thread was the expression by some of the participants to start remedial lessons in their respective schools. The trainee teacher at a school that does remedial lessons shared her experiences and taught the group how to conduct a remedial lesson. This exchange underscores the importance of sharing feedback through *WhatsApp* forum. It elucidates hidden issues and lessons that could not be captured from a survey or once-off visit to the school.

**Teaching methods**

The participants noted that their supervisors were not doing experiments during their lessons. Another reported that her school supervisor said he/she does not do experiments because there was no water in the laboratories. This let down denies the trainee teachers the opportunity to emulate use of experiments from their mentors. If trainee teachers do not grasp the skills in using experiments, they may not use it as well. In the end they will take after their supervisors and deny their pupils from learning science through use of experiments.

The group discussions revealed that trainee teachers wanted to have interactive lessons, though at times they felt there was nothing they could do to make the lesson interactive.

**Teaching/ learning aids**

Where a trainee teacher needed a particular teaching/learning aid, they freely discussed it and sometimes borrowed from the others. For example, one requested a variegated leaf. Trainee teachers were anxious to use teaching learning aids in their lessons. When they found that the schools did not have readily available aids, they asked their colleagues what they could use. The constant asking of material from others could be an indication that the trainee teachers were not adequately prepared to think outside the box and improvise. It could also point to the limited support they were getting in their schools.

**Laboratory equipment**

The group chats showed that teaching practice schools in the region were not equally equipped with laboratory equipment. Some schools appeared to have an adequate supply of laboratory equipment while others were poorly equipped. In some schools it was so bad that one trainee teacher expressed concern that they would not be able to deliver real science lessons. This sentiment is worrisome because it points to a gap on trainee teacher's inability to improvise. Since the trainee teachers were struggling to find laboratory equipment, it appeared none knew that they could borrow from the college science laboratories. This became apparent in follow-up interviews after teaching practice, that trainee teachers were not aware that they could use some of the laboratory equipment from the college laboratories.

**Pupils' behaviour**

Most trainee teachers had difficulties coping with student behaviour challenges. They appeared unprepared to handle discipline cases and some felt they could not cope. It appeared as if schools handled corporal punishment issues differently. In some instances, trainee teachers felt pupils with learning disabilities were not exerting themselves enough. One expressed exasperation at low achieving pupils in her class and expressed that she only works with those who want to learn and would ignore those who were not serious with their studies. She expressed this by saying "I only teach those that are teachable". However, a colleague of hers advised her to "cater for all learners". This exchange underscores the importance of a group chat that gives feedback immediately, rather than waiting for the whole term while still trying to figure out what to do with pupils who had difficulty grasping concepts.

Trainee teachers expressed disgust at some of the misbehaviour by pupils. Female trainee teachers were shocked to get admiration from their teenage boy students. One reported that young school boys were whistling at her while another said that they had told her that she was beautiful. This unnerved the trainee teachers, showing that they were ill-prepared for the attention they got from the male student admirers. This discrepancy could be attributed to college's inadequacy in psychologically preparing trainee teachers to deal with diverse learner cultures and backgrounds.

**School supervisors**

Each trainee teacher was assigned an experienced science teacher to supervise and guide them throughout the entire teaching practice period. There was a discrepancy on the quality of school supervisors given to the trainee teachers. Some school supervisors seemed to be very professional and the trainee teachers were happy with them. However, in some schools the trainee teachers complained that their supervisors were not committed to their duties, to such an extent that they would 'dodge lessons' and expect the trainee teacher to cover for them. This is contrary to the college expectation of a school supervisor who is expected to mentor the trainee teacher. In addition, a school supervisor who is not performing up to par is counterproductive because the trainee teacher does not benefit as expected from the mentor-mentee relationship.

In some instances, there were observed cases of teachers not scheming, not using teaching/ learning aids/ not doing experiments. The participants noted that their mentors did not use any teaching/learning aids during their lessons, exclaiming "*teaching aid zero!*" In another school a trainee teacher said the school mentors were neglecting their students by teaching "*without teaching aids, without experiments*".

"*My supervisor o betsa ka go sign hela*", meaning my supervisor just signs without reading. This was said by one trainee when asked to share her lesson plan in the group. It was her way of expressing non-confidence in her checked lesson plan because she knew that even though the supervisor had signed, the lesson plan had not been checked. One trainee teacher reported that her school supervisor taught three different classes under her watch, but none had a lesson plan. This was a bad example to the trainee teacher and illustrates that the supervisor cannot be trusted to help the trainee teacher in her knowledge gap on lesson planning.

The unprofessional behaviour of some school supervisors, though not common across all schools, makes the researcher question: are our school supervisors trained enough to mentor trainee teachers? The college had made the assumption that all school supervisors would use their experience and assist the trainee teachers in their pedagogical knowledge and practice, but they were not doing so.

### Comparison with University of Botswana teaching practice students

I was impressed that college trainee teachers, who were studying for a diploma, were not intimidated by degree and post graduate trainees from the university. One even had the boldness to state that with their diploma in waiting, they are better than University of Botswana (UB) students. They expressed confidence in their training when they compared themselves with peers from the university.

### Discussions

This section analyses the trainee teacher's knowledge gaps as viewed through the Shulman (1987)'s categories for teacher knowledge: content knowledge, general pedagogical knowledge, curriculum knowledge, learner characteristics, educational content and educational ends, purposes and values.

### Content knowledge

From the *WhatsApp* chat discussions, it was apparent that trainee teachers' knowledge was stronger in content than in pedagogy. This is attested by the fact that the perceived knowledge gaps deduced from the chats were mostly on pedagogical knowledge. During the entire teaching practice period only two questions or concerns were raised concerning content. One was asking about limewater as a test for carbon dioxide while another was on examples of amphibians. The concern on limewater was that it does not turn cloudy when carbon dioxide was bubbled through it. This failure to turn was contrary to what they know from chemistry content. The trainee teachers failed to explain this failure of carbon dioxide to form an emulsion when there is carbon dioxide. The researcher thus concludes that all members in the chat group did not have the chemistry content knowledge to explain this phenomenon.

It could be true that trainee teachers were stronger in content knowledge than pedagogical knowledge since science content is allocated nine (9) hours teaching time per week while pedagogy is given a third of that (3 hours). However, another explanation for the apparent strength in content knowledge is the availability of content knowledge in text books, internet, supervisors and other science teachers in the school. This would mean that trainee teachers would consult relevant sources prior to asking their peers on *WhatsApp*. Herold and Waring (2017) have shown that content knowledge gives teachers the confidence to teach, thus this perceived content knowledge gives the trainee teachers the confidence that they need to teach. In light of the foregoing, the researcher wonders if it was not time to balance the time allocation between content and pedagogy in science lessons. However, this requires further research and benchmarking from comparable teacher training institutions.

### General pedagogical knowledge

The themes that fall under general pedagogical knowledge gaps were scheme of work, lesson introductions and lesson planning. School supervisors serve the important function of guiding the trainee teachers' daily practice and help them make the transition from college students to school teachers (Teaching Practice Department, 2015). Though supervisor attitude is not a perceived knowledge gap, it directly affects the trainee teachers' performance in their teaching roles. If supervisors were not setting a good example, did not offer support, the trainee teachers' knowledge gaps became more pronounced and unmet.

The inconsistency between schools and college scheme of work requirements is worrisome and requires further investigation. It showed that the mentoring that the college expected from schools may not be enough since the trainee teachers at times were more professional than their supervisors, contrary to expectation as expressed by van Ginkel, van Drie and Verloop (2018). What was interesting to note on the thread of discussion on scheme of work was that trainee teachers were able to assist each other and offer helpful guidance. It also highlighted the difference between science and mathematics and gave the researcher meaningful insights that could open avenues for benchmarking with mathematics department.

The trainee teachers were cognisant of the fact that they had to make lesson introductions creative while at the same time taking pupils from the known to the unknown. This was one perceived knowledge gap where the trainee teachers did not feel helpless. They were able to refer each other to other sources outside themselves. In their comments they strived to help each other bring real life situations as part of the previous knowledge.

### Curriculum knowledge

Curriculum knowledge refers to "tools of the trade" that teachers need to deliver their content (Shulman, 1986). It includes teaching methods, strategies, teaching /learning aids. This area was rarely mentioned directly. State of laboratories and laboratory equipment made an indirect reference to this knowledge. However, trainee teachers did not perceive it as a professional knowledge gap in themselves, rather as could be a hindrance to effective classroom delivery. Trainee teachers shared ideas on teaching/learning aids, especially when they were discussing about how to introduce a lesson. Some shared worksheets while others made reference to the "*good stuff*" on the internet.

Shulman (1986) emphasises the importance of this aspect by comparing it with a physician who does not know the alternatives of dealing with a certain medical problem. This means that trainee teachers should be in a position to improvise their teaching strategies, suggest alternatives to audio-visual materials in order to make their lessons interesting and relevant. For those who referred others to the internet to check out the "*good stuff*" on worksheets shows that they were able to think outside the box and help themselves solve the manifesting problem, instead of depending on answers from the group chats. What I observed was that the trainee teachers made an attempt to assist each other so as to make the lessons interesting with reference to everyday life examples.

**Knowledge of learners and their characteristics**

The fact that one trainee teacher felt that she could not accommodate slow learners in her class meant that she lacked knowledge of how to teach a mixed ability class. The same frustrations were echoed by participants in a study by Kiggundu and Nayimuli (2009). The temptation to exclude slow learners in the class could be attributed to the trainee teacher's knowledge gap on handling pupils with learning disabilities. In addition, this could also be due to knowledge gap on educational contexts which will be discussed in the section on knowledge of educational contexts. Secondly, dealing with pupils' behavioural problems fazed the trainee teachers. They could be better prepared to handle different characters in their classrooms through exposure to real school based practice sessions prior to the teaching practice period. They would not be as shocked and appalled by the behaviour of pupils towards them.

**Knowledge of educational contexts**

A trainee teacher who wanted to ignore less able learners in her class showed ignorance of the country's educational contexts such as Sustainable Development Goals (SDGs), inclusive education policy as well as the spirit behind the Junior Certificate science syllabus. The syllabus is premised on the concept of inclusion, hence the need to create an enabling environment for all groups of learners, regardless of their physical, intellectual or emotional challenges (Republic of Botswana, 2008). A child cannot be discriminated against because of his/her learning disability.

While some schools welcomed trainee teachers and executed their mentoring job perfectly in the trainee teachers' view, other schools were less than welcoming. In some instances, trainee teachers' expectations clashed with the school mentors' dispositions. There were school mentors who were not ready to mentor the trainee teachers and this brought frustration to the trainee teacher.

These school mentors did not check trainees' lesson plans, had no scheme of work and were an overall bad example to the trainee teachers. This meant that the trainee teacher had to be ready and willing to quickly adapt to their teaching and learning functions (Gube & Phillipson, 2011) since there was nobody to ease them into the world of teaching. These mentors made the researcher to question the value or lack thereof that these school mentors were bringing into the trainee teachers' professional knowledge. If the mentor is not up to par, then our trainee teachers would not benefit maximally from the teaching practice experience. This observation has highlighted the need for closer interaction between the college lecturers and trainee teachers at teaching practice.

In addition, there was disparity between schools across the region. Some trainee teachers had fully equipped laboratories while others had limited material. This cannot be blamed on the government, who funds schools equally. The problem could be traced to the mentor teachers in the schools who failed to order laboratory supplies. Closer interaction between the college and the trainee teachers could offer alternatives to the trainee teachers. For example, the trainee teachers could borrow some of the laboratory equipment from the college.

**Knowledge of educational ends, purpose and values**

The Botswana science syllabus dictates that science should be taught from a constructivist paradigm, and learner centred methodologies should be employed (Republic of Botswana, 2008). There were instances where trainee teachers demonstrated lack of knowledge in some topics where they felt that they could not do any activities with their learners. This posed a knowledge gap that needed to be addressed, where trainee teachers felt they could not come up with hands-on activities for their learners.

## Conclusion

This research sought out to determine science trainee teachers' perceived knowledge gaps using Shulman (1987)'s categories of teacher professional knowledge. Trainee teachers showed strength in content knowledge compared to other teacher professional knowledge categories. The trainee teachers' perceived knowledge gaps were in the following areas: scheme of work, lesson introduction, lesson planning, assessment, teaching methods, teaching/learning aids, improvisation of laboratory equipment and handling of pupils with learning and behaviour problems. These are in the categories of general pedagogy, learner characteristics, educational contexts, ends and values. The identified knowledge gaps point to three aspects. Firstly, the trainee teachers were not adequately prepared by the science department to handle some of the challenges they experienced at teaching practice. Secondly some of the perceived knowledge gaps were compounded by inadequate supervision by the school supervisors. Lastly, the findings brought to the fore the support provided by *WhatsApp* interactions during teaching practice. The group chats provided trainee teachers with the much needed support that they could not get from the college lecturers or from the school supervisors.

## Recommendations

1. The Department of Science should consider balancing contact time for science content and pedagogy.
2. The Department of Science should expose trainee teachers to the school classroom environment prior to teaching practice sessions.
3. The Department of Science should establish a mutually beneficial relationship with science teachers in the schools so that the college expectations of school supervisors are met.
4. Science lecturers should intensify the support given to trainee teachers during teaching practice.

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**Article 2**

# Promoting continuous teacher professional development through school based INSET for sustainable development: The Dagoretti lesson study model approach

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**Abstract**

Effective teaching requires considerable knowledge and skill, which should be developed throughout a teacher's career progress and the most effective professional development practices are the ones focusing on best classroom practices.

Dagoretti lesson study pilot was meant to test a model which would take the practice to a higher level and also fit into the dynamics of the changing time. It was done with nine mathematics teachers from each of the nine schools in Dagoretti sub county in Nairobi county, Kenya who formed a community of practice (COP). After ground rules, familiarisation, and objectives setting, it was trained on steps of lesson study, ICT integration, STEM education, Pedagogical content of the teachers were arranged such that they all had 2 hours per week where all could meet for professional development through lesson study.

They then went through all the steps of the lesson study which included, problem identification, lesson planning and lesson implementation which was done by one of the teachers on a school which was not his own and then lesson reflection.

Dagoretti lesson study model is a case study of successful classroom-based professional development of a community of experts.

**Key words:** *Case study, Classroom practice, Contextualised, Lesson study, Pedagogy, Professional development.*

**Abbreviations and acronyms:** *ASEI-Activities, Students, Experiment, Improvisation, CEMASTEA-Centre for Mathematics, Science Technology Education in Africa, CD-County Director, CDE-County Director of Education, COP-Community of Practice, HOD-Head of Department, ICT-Information, Communication Technology, INSET-In-service, Education and Training, MOE-Ministry of Education, NESP-National Education Sector Programme, PBL-Project Based Learning, PDSI-Plan, Do, See and Improve, QASO-Quality Assurance and Standards, SC-Sub County, SDGs-Sustainable Development Goals,* *SMART-Specific, Measurable, Accurate, Reliable, and Time bound, STEM-Science, Technology, Engineering and Mathematics, STI-Science, Technology and Innovations, TPD-Teacher Professional Development, TSC-Teachers Service Commission, UN-United Nations*

## Problem Statement

Effective teaching requires considerable knowledge and skill, which should be developed throughout a teacher's career progress. High-quality professional development requires workplaces to be steeped in rigorous updating of best practices, with professionals continually developing and supporting each other. It can take many forms, but the best available evidence shows that the most effective professional development practices are the ones focusing on best classroom practices.

Also learning by students can be improved significantly by addressing instructional problems, and increasing teachers' knowledge of content and effective pedagogies. Active learning is one of such strategies that place learners at the center of teaching. It encourages them to construct meaning by actively combining knowledge with experience, as teachers provide support mechanisms for them to connect new knowledge with prior knowledge

Although teachers learn about principles and the importance of learner-centered teaching and learning approaches during pre-service, their actual practice in class is still insignificant.

The job market requires graduates of schools to be critical thinkers, innovative, creative and problem solvers for the advancement of society (Keengwe,J.et al 2008). The reluctance to shift from teacher centered to learner centered is highly influenced by a teachers' own concept of what is teaching (V. Mellado.,et al.2007).

This situation can be resolved through effective professional development programmes that provide teachers with opportunities to improve their content, pedagogical and technological knowledge in a contextualized way. This helps builds their capacity to facilitate students to learn by themselves, make learners interested in what they learn, relate what is new with their previous knowledge and applying knowledge learned to different situations (Soonhye P., et al)

In Kenya today there is no well-established school- based teacher professional development programme.

## School based lesson study:

School based lesson study is about improving teaching skills. It is a situation where teachers teaching a particular subject in a given school or area come together; plan a lesson, discuss the lesson, then one of them teaches the lesson as the others observe. There after they hold a discussion on how the lesson was taught ways in which it could be improved.

The lesson study can be based on the theme which is developed by the group or research team and is determined by the current situation of the learners.

**Zonal/Area/Cluster based:**

This is inter-school lesson study groups which are subject oriented.

**Steps of lesson study**

There are four main stages of lesson study:

**1. Identification of the theme and the problem**

The teachers identify the challenges or difficulty areas in the teaching and learning of the subject.

Thereafter they agree on the topic of which the lesson is to be prepared.

**2. Lesson preparation or planning**

The planning of the lesson is done collectively by all the teachers

**3. Implementation**

Conduct the lesson, with one team member teaching and others gathering evidence on student learning and development

**4. Feedback**

Discussion on the evidence gathered during the lesson, with an aim to improve. The teacher who taught starts by giving his comments about the lesson and then observers give theirs. The lessons learnt are to be incorporated in all other lessons.

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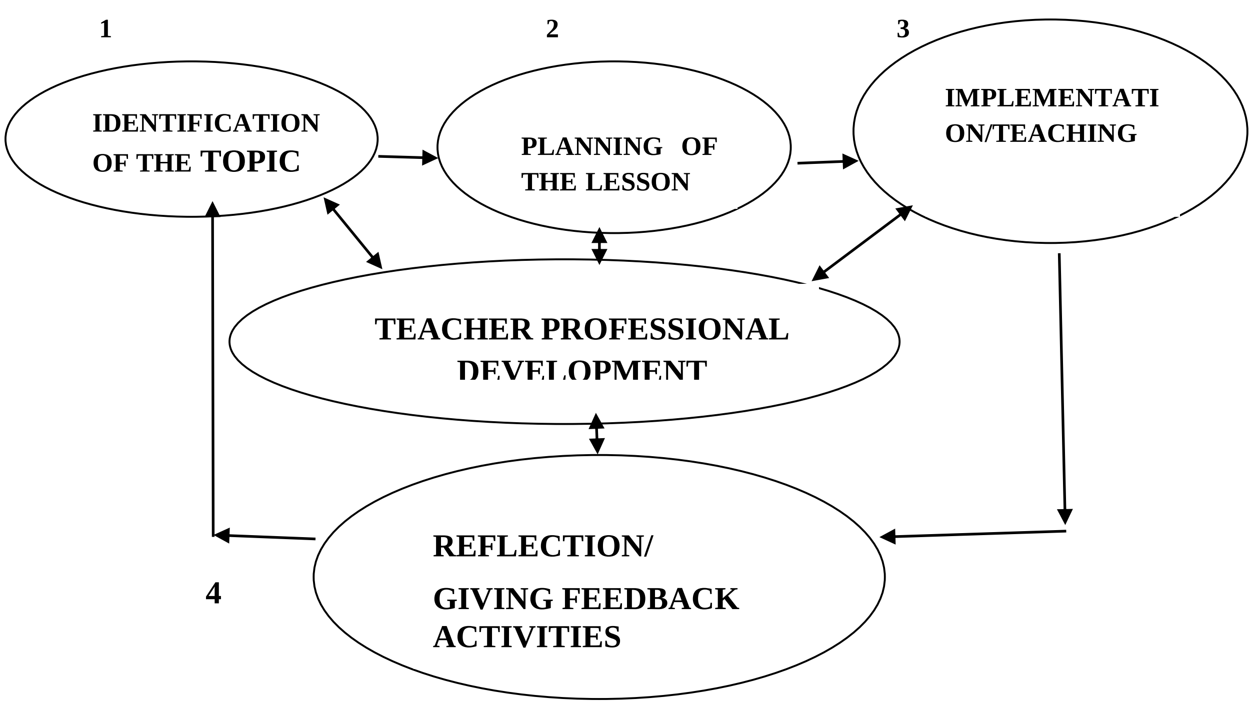


*Figure 1. The above diagram illustrates the 4 stages of Lesson Study*

## Roles and responsibilities

For lesson study to be effectively carried out various stakeholders must play their roles.

**Principals/Head teacher:** To coordinate and supervise the exercise.

**Head of department:** This would be the head of the technical team and would guide the team in coming up with the theme and the topic to be taught.

**Teachers/group members:** They should participate in the whole process

**Expert:** Should be an experienced technical person in the subject giving meaningful feedback.

## Conclusion

The effective adoption of the lesson study approach to improving pedagogical skills in teaching and learning can enable teachers to understand that active or student centered learning is a result of active teaching, to appreciate and understand the power and benefits of research and team teaching in the classrooms, develop lessons together, learn to engage and motivate students through ICT integration, develop ownership of instructional process through contextualized authentic experiences.

**''Dagoretti sub county mathematics teachers research group lesson study model''**

**Policy: The** Constitution of Kenya, 2010, guarantees quality education to every citizen and Vision 2030 purposes at transforming Kenya into a newly industrialized, "middle-income country by providing high quality life to all its citizens. Quality education especially in Science technology and innovations (STI) is cited as a key enabler in achieving that goal. In the United Nations (UN) Sustainable Development (SDGs) Goals No 4 is to ensure inclusive and quality education for all and promote lifelong learning.

The Sessional Paper No. 14 (2012) on Policy Framework for Education, Training and Research, recognizes the broad opportunities afforded through Continuous professional development in "providing new opportunities for teaching and learning, including, offering opportunity for more student centered teaching. The Ministry of Education (MOE) recognizes In-service Education and Training (INSET) as an investment programmes in the NESP document (2015).

Also, *under Article 237(2) of The Constitution of Kenya, the Teachers Service Commission (TSC) is mandated to* review the standards of education and training of persons entering the teaching service

Centre for Mathematics Science and Technology Education in Africa (CEMASTEA) mandate is to capacity development of teachers especially for Mathematics and Sciences. This is done through INSET.

**The Model**

CEMASTEA has been conducting lesson study since 2009 and the piloting in Dagoretti subcounty was meant to test a model which would take the practice to a higher level and also to fit into the dynamics of the changing time.

**Theme:** 'Revolutionize the teaching and learning of mathematics in Dagoretti through innovative classroom practices''

**Overall goal:** Make Dagoretti subcounty a model subcounty in the teacher professional development practice through classroom-based teacher research.

**Objectives**

1. Form communities of practice/experts
2. Form sustainable cluster based continuous professional development system

**Expected outcomes**

A community of practice established and enhanced quality of teaching and learning

**Steps**

1. **Formed coordination team**

This comprised of local education administrators and the head teachers.

Their role was to coordinate activities, invite teachers for meetings, develop an implementation schedule, organize to have a free afternoon when all teachers can meet.

**Teachers Research Group Members**

At least one mathematics teacher from all the nine schools in the group (preferably Head of Department (HOD)

Their role was to participate in TPD, identify problems, undertake content and pedagogical research, plan lessons together, implement the lesson and participate in the lesson reflection.

One teacher pulled out after the induction due to personal reasons

**CEMASTEA**

The role was to provide technical support, sensitize and train teachers, monitor progress, evaluate, document and review progress.

**First meeting of the teacher research group**

The members agreed to form a COP named Dagoretti subcounty mathematics research group, identify needs of teaching and learning mathematics in Dagoretti, be research oriented on content and pedagogical issues with an aim to teach innovatively, organise a time to be free on Friday afternoon to ensure no teachers misses class, to form a WhatsApp Group and Google Groups, the former is for administration while the latter was for sharing teaching learning resources online.

**Situation analysis**

The group identified the following as teaching and learning challenges in Dagoretti subcounty;

Negative attitude, abstract concepts, lack of interpretation and application skills, the student's tendency to copy homework and present it as his or her own, over reliance on the teacher by the student rendering them too dependent, no logical reasoning, inability of the students relating what they learn in class to the outside world and inability of students to work as teams.

**Induction of the group by CEMASTEA**

Group members were inducted on the following as per the needs assessed:

**ASEI-PDSI**

Members were taken through the principles of Activity, Student, Experiments and Innovations (ASEI) and Plan, Do. See and Improve (PDSI). PDSI is the vehicle used to carry ASEI. The rationale of ASEI- PDSI advocates for a pedagogical shift from teacher centeredness to learner centeredness. Evaluation is strongly based on the achievement of lesson objectives under the following cyclic frame:

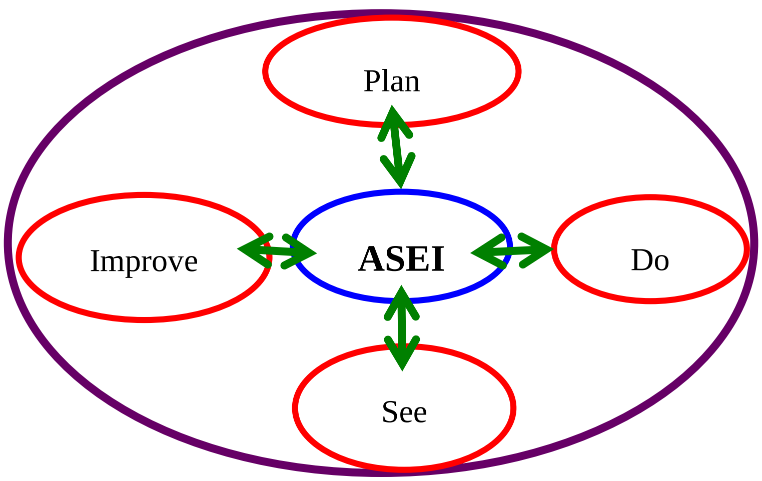


***Figure 2***

**STEM education**

**STEM** stands for **S**cience, **T**echnology, **E**ngineering and **M**athematics. It aims to demystify scientific terms through: Integration of concepts that are usually taught as separate subjects and emphasizes on the application of knowledge to real life, it is based around finding a solution to real world problems and doing this using **P**roject **B**ased **L**earning (PBL).

**ICT integration in teaching and learning**

Members were introduced to ICT and ICT integration in teaching and learning

Emphasis was on how ICT can help transform the learning environment into one that is active and learner-centred.

**Lesson study**

Research group members were taken through cycles of lesson study

In lesson study the problem is the gap observed between the aspirations of teachers/ school have for their students and the actual state of affairs, lesson study should bridge this gap.

**Content and pedagogical research**

Content is primarily the subject matter and pedagogy implies the teaching skills

**Research** involves examining, investigating, study, observation, enquiry and exploration, but it need not be an extremely elaborate academic research.

**Research group implementation of lesson study**

**Steps**

**Problem identification**

The members isolated the following as prevalent: The rush by the teachers to complete the syllabus, the teacher's tendency of not granting the students a chance to make comprehensive contributions however inaccurate, teacher centred teaching, the teacher's failure to allow the student various options of arriving at a solution, questions administered not being open-ended and also which have no bearing on real-life experiences. The group agreed the lesson study theme was "**how to Promote independent thinking in students in Mathematics"**

**Methods/strategies suggested to be used to promote independent thinking**

To place students in ability varied groups and administer specific tasks for them to tackle, exercise patience when teaching and allow the students appropriate time to present their answers after asking a question or presenting them with a problem, asking probing questions, allowing the students make their own observations and arrive at their own conclusions and to give the students open ended questions.

**The following teaching methodologies were adopted:**

Inquiry based, exploration, open-ended questions, activity-based learning, manipulation, observation and conclusion. Members were then to individually come up with activities to promote independent thinking. The topic agreed was linear motion and the concept of speed in Form 2 as it was projected that, that would be the topic they would be covering during when the group would be teaching.

## Lesson planning

### a) Planning of the lesson 1

As a starting point, members discussed the aspects of a good lesson as: having "SMART" objectives, having a task for the learners to carry out, carefully chosen from the learners' immediate environment, and leading to discovery of the intended concept by the learners, tasks that are interesting and making learners curious to explore further. They should also make learners think deeply making meaningful learning to take place.

List of questions to be asked by the teacher which will enable them to draw appropriate answers from the learners, and a list of anticipated responses from the learners should be well prepared.

The following factors were also discussed as crucial in the process of lesson development: Need to tackle the terms used in the teaching of speed, one at a time, the concept to be taught will be speed and the planning process will reveal the expected time allotment. In the delivery of the lesson one ought to generate a situation in which there will be a real-life application.

It was agreed that members to prepare and to present the lesson on speed. The main function in the next session would be to fine tune the draft.

### b) Planning of the lesson 11

#### Presentations

All members made the lesson presentations

#### Discussion

Emphasis was put on the need to address the learner's independent thinking, and hence the members agreed to develop a hybrid lesson incorporating the use of ICT.

### c) Planning of the lesson 111

The draft lesson plan developed in the previous meeting was discussed at length and effectively adjusted to suit the requirements in readiness for the lesson due to be delivered.

The following aspects of the lesson plan were adjusted; Questions asked at the introduction stage were structured, considering that the students' pre-requisite knowledge and the video presentation to be re-done to capture three categories *viz,* students sprinting, jogging and walking so as illustrate the different paces presented by the three situations.

The data of the group activity to be presented and thereafter a conclusion drawn.

#### The mock presentation of the lesson

The lesson was presented, with the members playing the role of students. Correctional views were presented and the members agreed with the recommended adjustments.

One member, Mr. Stanley Okinyi, was identified to teach the lesson and was required to conduct a familiarization tour a day before to acquaint himself with the prevailing teaching/ learning environment and also check on the equipment to be used in the lesson. The lesson would be conducted at Ruthimitu Mixed Secondary School.

**Lesson implementation**

The research lesson was presented in Form Two at Ruthimitu Mixed Secondary School by Mr. Okinyi, a teacher at Dagoretti High School. Other members of the group were, education officials, CEMASTEA staff led by the former Director, Principals and the TSC officials were present.

The lesson was from the topic of linear motion and the subtopic/concept of speed. The problem identified which was being addressed was promotion of independent thinking in learners.

**Introduction**

The learners were asked to describe scenarios of how they go school and some said they walked, other used bicycles or motorcycles and other used vehicles. Through probing it come out that the distance remained the same but time varied depending on the mode of transport.

**Development**

Through group work they were given a table with times taken to cover the same distance by different persons and through probing again they were able to conclude that faster people were using less time to cover the same distance hence bringing out the concept of speed.

**Conclusion**

The teacher guided them to conclude that speed is the distance covered in a unit time.

**Lesson study Reflection:**

**Self-observation by Mr. Stanley Okinyi (Teacher conducting lesson)**

- Emphasis on the delivery of a concept at a time.

**Group observation**

The lesson brought forth the idea of the theme which was: Promoting independent thinking evidenced by using a variety of teaching aids, reinforcing the student responses, allowing the students to present their answers conclusively, data collected being relevant and allowing for student ownership of the lesson. Also using teaching/ learning scenarios that allowed for inquiry-based questions.

**Review meeting**

The genesis of the formation of the group was revisited for the benefit of all. The support from CEMASTEA and the Principals was acknowledged in making possible the realization of the group's collective objectives. It was noted that team teaching ought to be taken a notch higher and teachers to endeavour to grow professionally by posting lesson plans which they have individually or collectively developed through the Google+ forum so as to keep the academic fire burning. Dagoretti research group was to be a model of mathematics teachers with the best classroom practices in the country.

**Achievements of the pilot lesson study**

It was cost effective, teachers were not missing classes as a free afternoon had been created for them and teachers were enthusiastic

**Challenges**

The challenges included understanding the process in the beginning and coming up with the pedagogical problem to be addressed.

**The Dagoretti model: A new and effective model of teacher professional development**

This is a new mode of teacher capacity developed which has been piloted and has become a big success with wonderful results. It is very cost effective, teacher friendly and the impact is great.

It is classroom-based lesson study approach where teachers of the same subject come, identify challenges which affect teaching and learning in their schools, then plan lessons together which address the identified problems, one of the group members implements the lesson as the others observe and then they have a reflective meeting to discuss the lessons learnt which are to be replicated in future lessons. A community of practice is thus established and the process is repeated termly or yearly.

In 2017, the education stakeholders in Dagoretti subcounty in Nairobi who included, the SC TSC-CD, SC-CDE, SC-QASO and the principals in collaboration with CEMASTEA started a community of practice of one mathematics teacher in each of the 9 schools in Dagoretti subcounty with a view to improve the performance of mathematics in the subcounty. The group name was Dagoretti subcounty Mathematics research group.

After undergoing induction at CEMASTEA, the group executed all the steps of the lesson study cycle which culminated with the lesson implementation in September where all the stakeholders, the former Director CEMASTEA and a TSC representative were present. The research lesson focusing on promotion of independent thinking through inquiry based learning was taught in Ruthimitu Mixed Secondary School by a teacher from Dagoretti High school. It was also incorporating ICT integration.

**Main highlight of the model was;**

1. The teachers were meeting on a Friday afternoon where an arrangement had been made that they were all free such that no teacher was missing lessons
2. The teachers were from the same locality so the model was cost effective in both time and resources
3. CEMASTEA was providing the technical support
4. The model to be replicated in other clusters, sub counties or regions.

5. The model can work and can be replicated all subjects and not just mathematics
6. The skills learnt during a particular lesson study cycle can be applied in other topics
7. Schools forming lesson study group to organize their time tables to create an afternoon in a particular day where all teachers of the same subject are available for lesson study.
8. The lesson study group to became a community of practice which should continue and be a continuous professional development practice and for sustainability.

**Figure 3 Dagoretti subcounty Mathematics research group members engaging in a group discussion**

## Outcomes and impact

1. There was ownership of the process by the group members as they are addressing real problems identified by themselves
2. The mathematics results improved in 7 out of 8 schools which participated in the research even as the overall school of 7 out of 8 schools dropped.

### 2016/2017 Mathematics KCSE Analysis

| | **School** | **2016 mean** | **2017 mean** | **Deviation** | **Comments** |
|---|---|---|---|---|---|
| 1 | Beth Mugo Sec School | 1.688 | 2.029 | +0.331 | Improved |
| 2 | Ruthimitu Girls | 1.684 | 2.45 | +0.776 | Improved |
| 3 | Dagoretti High | 3.6 | 4.188 | +0.588 | Improved |
| 4 | Ruthimitu Mixed | 1.6931 | 1.95 | +0.25 | Improved |
| 5 | Nembu High School | 4.335 | 5.243 | +0.899 | Improved |
| 6 | Mutuini High | 1.589 | 2.55 | +0.961 | Improved |
| 7 | Precious Blood | 8.8108 | 9.6954 | +0.8840 | Improved |
| 8 | Dagoretti Mixed | 2.23 | 2.221 | -0.009 | Dropped |

Table 1.

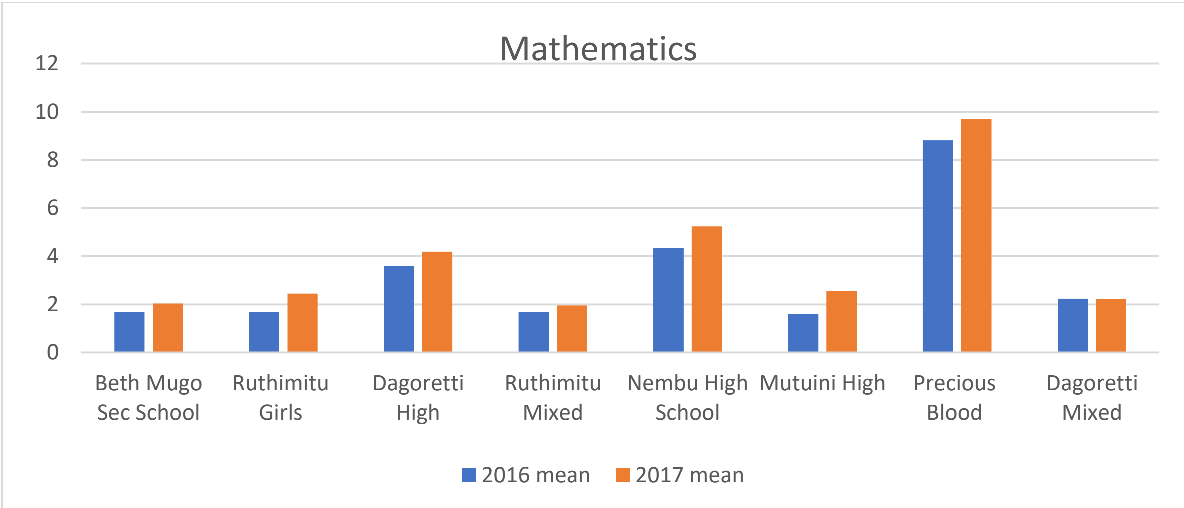


Figure 4 7 out of 8 schools improved

## 2016/2017 KCSE Analysis

| | School | 2016 overall mean | 2017 overall mean | Deviation | Comments |
|---|---|---|---|---|---|
| 1 | Beth Mugo Sec School | 2.587 | 2.588 | +0.001 | Improved |
| 2 | Ruthimitu Girls | 3.667 | 3.36 | -0.307 | Dropped |
| 3 | Dagoretti High | 5.234 | 4.624 | -0.61 | Dropped |
| 4 | Ruthimitu Mixed | 2.83 | 2.54 | -0.29 | Dropped |
| 5 | Nembu High School | 6.142 | 5.74 | -0.402 | Dropped |
| 6 | Mutuini High | 3.52 | 3.26 | -0.26 | Dropped |
| 7 | Precious Blood | 9.4662 | 8.9272 | -0.539 | Dropped |
| 8 | Dagoretti Mixed | 3.36 | 2.83 | -0.53 | Dropped |

Table 2

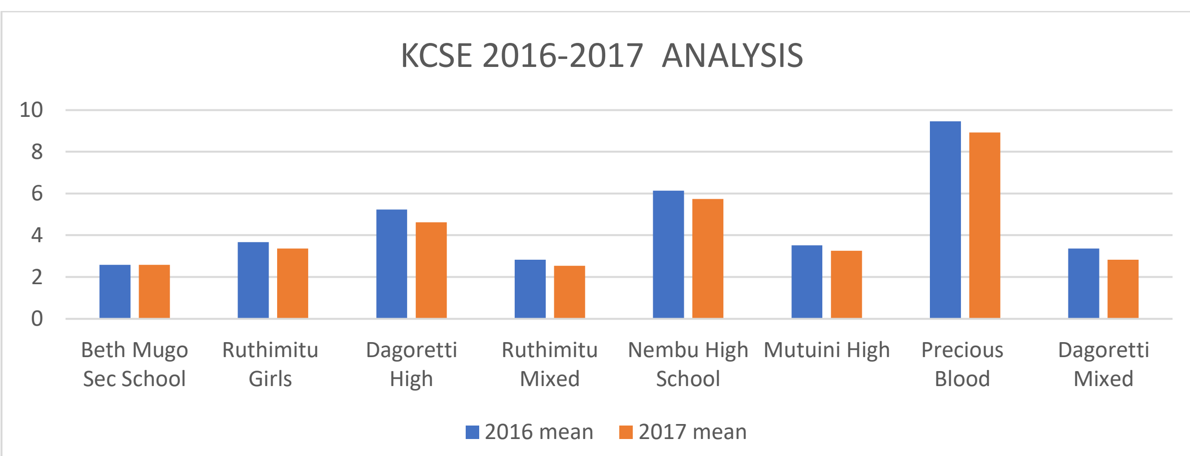


Figure 5 7 out of 8 schools dropped in KCSE but improved in mathematic

## The Dagorettti lesson study model

Summary of activities and practice of lesson study: The Dagoretti model

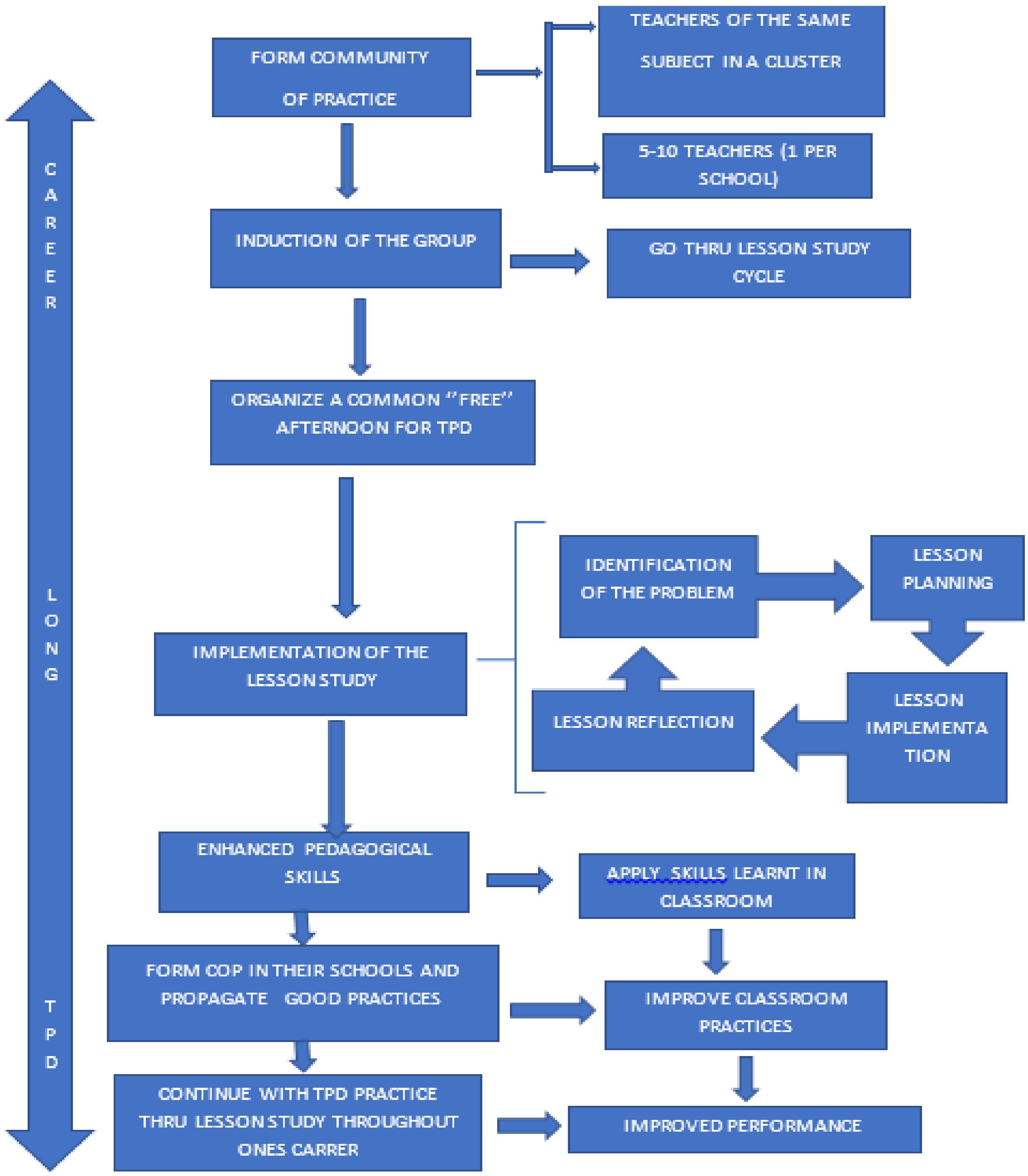


**Figure 6 The Dagoretti Lesson Study Model**

## Adoption

The Dagoretti lesson study model has been adopted and contextualized in Kenyan and is being rolled out to all counties through CEMASTEA

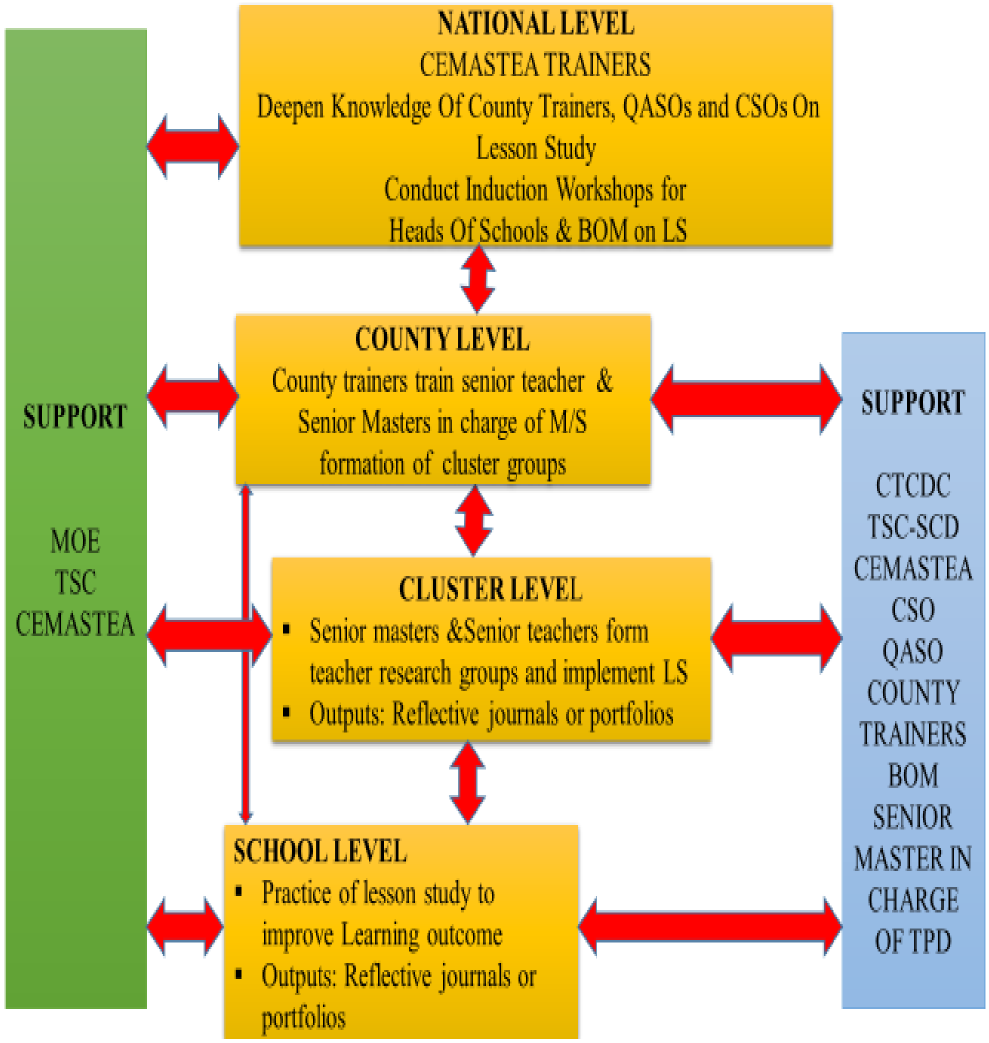


**Figure 7 Dagoretti Lesson Study Model as a proposed Model for Continuous Teacher Professional Development**

Following the success of the Dagoretti lesson study Model, it is proposed that it can be used for continuous teacher capacity development. This is the proposed model which has and is working for Dagoretti subcounty and can be replicated in the whole country.

**Proposed Model of**

**Continuous Teacher Professional Development (TPD)**

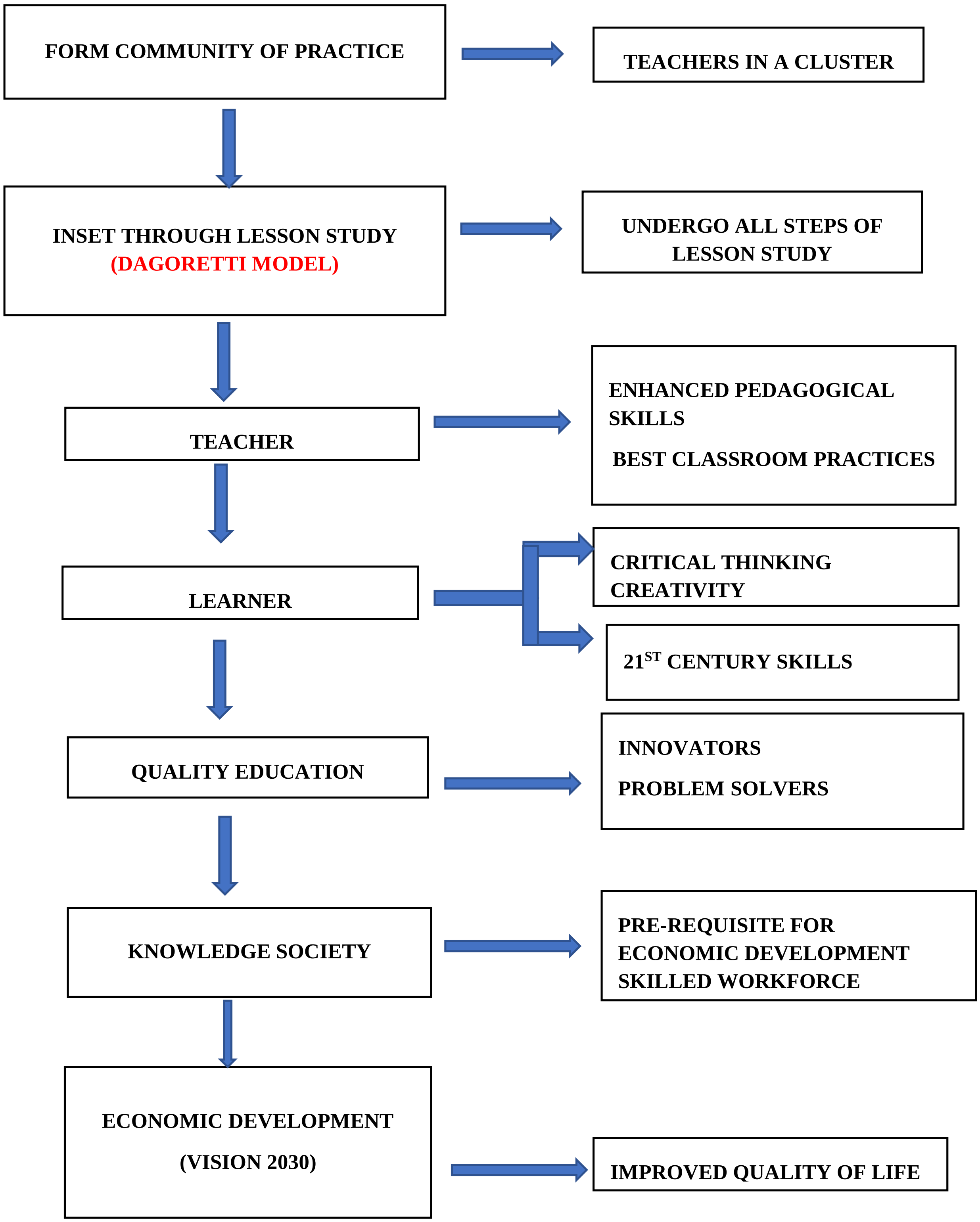

**Figure 8 Proposed Model of Continuous Teacher Professional Development**

## Conclusion

The model was a pilot project of how to create a community of practice for classroom based continuous professional development, was successful and cost effective.

Because, Kenya envisages being a middle level developed country by the year 2030. One of the catalysts is having a skilled workforce which can only be achieved by laying a good foundation in education. The quality of teachers who are acquainted with modern skills of teaching and learning is paramount in realization of this noble goal. This would help achieve sustainable development. This can effectively be envisioned through lesson study.

## Recommendations

i. The model can be replicated in other clusters, sub counties or regions.
ii. The model can be replicated all subjects and not just mathematics
iii. The skills learnt during a particular lesson study cycle can be applied in other topics
iv. Schools forming lesson study group to organize their time tables to create an afternoon in a particular day where all teachers of the same subject are available for lesson study.
v. The lesson study group to become a community of practice which should continue and be a continuous professional development practice and for sustainability.

## Way forward

i. The Dagoretti lesson study research group as a community of practice is currently continuing and doing the second cycle hence making it sustainable
ii. The teachers in the group have started school-based communities of practice in their respective schools to entrench the practice in the schools.
iii. Continuous teacher professional development can be carried out through the lesson study model.

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**Article 3**

# Integrated approaches in physics pedagogy; Active learning strategies in physics teaching

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**Abstract**

This paper shares the physics teachers' opinion about the students' centred activities applicable in context and as proposed for STEM structure subjects by SMASSE - CEMASTEA. The paper describes strategies that can be adopted to help educators; build an integrated understanding of various elements of Physics Education Research (PER), including teachers' skills, reform-based curricula together with evidence of their effectiveness. The objectives are; to present the appropriate specific methods for physics pedagogy; to develop physics teaching styles; propose planning format and guided discussion for learning physics; and develop effective laboratories for learning physics that infuse ICT. Since the launch of Digital Literacy Program (DLP) in Kenya in 2016, the government delivered computers to schools making it an ideal ground for trying schemes to use technology in teaching Physics. Teachers need to give attention to both content of course and process of moving students from the initial stage of understanding to the level desired since physics as a multidisciplinary subject, its teaching should have ways and means to broaden content in the subject to enhance learning like incorporating project work currently missing in secondary school evaluation process. More assessment in the affective domain is proposed too to improve performance of physics.

**Keywords:** *Physics pedagogy, learning Strategies in physics*

**Abbreviations:** *CEMASTEA-Centre for Mathematics Science and Technology Africa, DLP-Digital Literacy Program, ICT-Information Communication and Technology, PER-Physics Education Research, STEM-Science, Technology Engineering and Mathematics*

## Introduction

The core purpose of education is to guide learners through a course path so as to create an individual who has values for the society he/she is going to serve in. The prepared learner should not only grow in cognitively but also his/her psychomotor skill and affective domain of learning should be developed by the process. A learner should be well prepared to face the challenges of the ever dynamic world by being versatile to cope with this fast changing and unpredictable world. Physics as a subject has been has been having fewer students opting for it at high school level, with even a smaller number taking it as a subject at post secondary school education. This can be attributed to the methodology used in teaching physics at high school level creating a feeling that the subject is difficult.

**Statement of the Problem**

The subject physics for a very long time has been perceived as a difficult subject. Around the world, there is a decline of youth interest in science and particularly physics. There are diverse and complex reasons why young people are not interested in science (Donaldson, 2015; Baser, 2006). Kalem (2009) points out that the abstract nature of scientific knowledge hinders the acquisition of scientific concepts. Research indicates that the source of this problem lies in the difficulty of meeting the objectives of experiments in laboratories (Hofstein, 2003). Other researches emphasize the danger of learners' conceptions in the teaching and learning process (Sivan, et. al, 2000). From another perspective, studies have shown that the challenge is not only in the knowledge itself, but also in the teaching practices (Scholes, 2002). To industrialise as a country, STEM subjects needs to be embraced with physics at its core. The teaching and learning of physics requires a great paradigm shift to make it effective and therefore create a pool of creative physicists in future to drive the industrialisation agenda of the country.

**Literature on Active Learning Strategies**

Active learning is generally defined as any instructional method that engages students in the learning process. Simply put it, active learning requires students to do meaningful learning activities and think about what they are doing (Kim et. al, 2010). While this definition could include traditional activities such as homework, in practice active learning refers to activities (demonstration, group working etc.) that are introduced into the classroom (Sweller, 2006). In other words, all learning is in some sense active, but active learning refers to the level of engagement by the student in the instructional process. An active learning environment requires students and teachers to undertake to a dynamic partnership in which they share the responsibility for instruction (Kim et. al, 2010).

Meyers & Jones (1993) maintained that the active learning consists of three factors that are interrelated. These are: basic elements; learning strategies; and teaching resources. The basic elements of active learning are speaking, listening, reading, writing and reflecting. These five elements involve cognitive activities that allow students to clarify the question, consolidate and appropriate the new knowledge. The second factor of active learning is the learning strategies that incorporate the above five elements. These are small groups, cooperative work, case studies, simulation, discussion, problem solving and journal writing. Third factor of active learning is teaching resources that the teacher uses to encourage students to interact and participate actively in the activities.

In the light of the results of the studies presented above, it is determined that attitudes and successes of the students are effectively increased by using active learning techniques. Through this point of view, it can be clearly claimed that active learning is an effective way of teaching. Examining some studies, it indicates that the concepts and subjects about science - physics in particular are not easily understood by learners and creates some confusion (Yin, 2003; Merriam, 2004; Karamustafaoglu & Karamustafaoglu, 2001).

It is possible to make them clear by teaching these concepts more concretely and through research, observation and experiments. Learners should be encouraged by assigning them responsibilities and helping them to develop their creativeness. It is accomplished through active learning methods. However, examining the related literature, it is obviously observed that there is not any knowledge how much the active learning approached is used for the physics teaching. For these reasons it is necessary to examine the reasons why the active-learning is not used to yield permanent learning. The number of researches carried out on active learning is not sufficient to determine that whether it is as successful as in other countries. Therefore, we need to find answers to the following questions (Hollingsworth, & Ybarra, 2008).

i. How often do the teachers use student-centred active learning techniques in physics teaching?

ii. Do they have sufficient knowledge about active learning techniques?

iii. Do they have enough opportunities to realize them in their classes?

Moreover, teachers do not perceive the fully the differences between traditional teaching and active learning. They are not willing to change their point of view when they think of transforming traditional teaching to active learning. As they encounter new obstacles for new forms of material. SMASSE inset training has been successful in imparting knowledge of hands-on activities and innovativeness on the side of teachers. But research has shown that the practicability of this has had many challenges due to the quantity of content at high school level viz-a-viz the pressure for syllabus completion

**Suggested Strategies for Active Learning**

The Kenyan curriculum is packed with so much content that teachers resort to telling students what they know and students simply commit facts to memory. The packed curriculum leaves little time for students to acquire a deep understanding of the subject or to develop life-long skills such as critical thinking, problem solving, and communication. However, learning is not committing a set of facts to memory, but the ability to use resources to find, evaluate, and apply information.

This paper addresses these concerns by discussing “how we learn” and reviewing the literature on what works to improve learning. It is clear that active processing of information, not passive reception of information, leads to learning. That is, students must construct their own understanding of concepts, relationships, and procedures. Teachers can encourage this process by carefully considering the type and organization of information as well as instructional strategies. Specifically, teachers should reduce the total amount of factual information students are expected to memorize, reduce our use of the passive lecture format, and devote much more effort to helping students become active, independent learners and problem solvers. Collaborative learning activities, interactive models, educational games, project works, and establishing a culture of inquiry/scholarship are critical for achieving these goals. “There is a great difference between teaching and learning. There is too much teaching and not enough learning” (McClanahan & McClanahan, 2003). Teaching is not telling students what we know but showing students how we learn.

One way to achieve this goal is to reduce our use of the passive lecture format. Before the development of the printing press, the only way to transmit information was by word of mouth. However, with printed materials and electronic resources, other means of information delivery are now available. In fact, with the explosive development of the internet and other technologies, teaching resources have seen a revolution that rivals the invention of the printing press. Why, then, does lecturing remain the predominant form of teaching in secondary and postsecondary education (McClanahan & McClanahan, 2002, Hollingsworth & Ybarra, 2008; Mulholland & Turnock, 2012)? It is true that lecturing facilitates the sharing of information with a large number of students and that lecturing may be effective in transmitting factual information (Prince, 2004; Bonwell and Eison, 1991). However, lecturing merely exposes students to content, and exposure is not sufficient for learning. Active processing of information, not passive reception of information, leads to learning (Prince, 2004). That is, students must construct their own understanding of concepts, relationships, and procedures. Teachers can encourage this process by carefully considering the type and organization of information as well as instructional strategies (Prince, 2004). However, lecturing should not be the instructional strategy of choice for Physics.

Creation of active learning activities like project works for physics will create a new way of thinking in the physics students, whereby they will think and reason in a scientific way. If such kind of mind is created in the physics students, attempting questions and solving problems in physics and in day to day life will be easier as they will apply scientific reasoning and follow the scientific process to successfully solve a problem rather than try to recall what skills to apply in life situations. Learners will be learning by developing critical thinking minds, problem solving skills and communication.

In addition, physics teachers can create a joy, an excitement, and a love for learning. They must inspire and engage students and show them how we learn rather than tell them what we know.

## Methods for Solving the Problem

Use of cell schools in a sub-county can be adopted to implement use of project work at all levels of secondary education with regular physics teachers in the identified cell schools prepared for the project over one school holiday period. The teachers will then prepare teaching and learning materials that will guide students to project work in topics they are to carry out during school session. The materials are to be evaluated before use and the implementation be monitored over the school period.

Students performance can then be evaluated and comparison done on the trend of the performance per cell school. Questionnaire and focus group interviews can then be carried to ascertain the appropriateness of the pedagogy in meeting the set objectives of learning.

When we are truly successful, our students will be impatient to study, reflect, contemplate, and really learn. Teachers should engage students in science and engineering fair as presenters and as participants. From such an interaction, the students will be exposed to scientific processes and create in them a scientific way of thinking and solving physics and day to day challenges in life.

The feedback results are an upward trend in students opting for physics as a subject since it is made more interesting and fun to practice. With a higher number of students taking physics as an optional subject, lower level classes will have a shift in their perception of the subject and therefore the traditional mindset of physics being a difficult science will be fading.

## Conclusion

Physics pedagogy needs to take a different dimension. Creation of scientific mind and skills should be the focus strategy. Physics teachers should embrace project work and students' engagement in the learning process to make it successful and create a society with physicist who can drive the country's agenda of industrialisation.

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**Article 4**

# The innovative teacher: A pinnacle of the 21st century learner-centred teaching of Biology

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**Abstract**

Performance in Science Double Award students in Botswana was declining: impeding such students to pursue science -based careers which are the pillars for commercialization of innovative projects to create employment. The researcher was prompted to find ways to unravel the lack of passion and curiosity among these learners. Findings on a study conducted at Kagiso Senior Secondary School in Ramotswa, Botswana are reflected on this paper. Quantitative and qualitative methods were used to investigate if learner-centered approach improves performance. A sample of **75** students from an enrolment of 979 learners was used. Interviews and inventory tests were conducted to seek learning styles, multiple intelligences and personalities. Such information influenced the researcher's choice of lesson activities and learning aids for each distinct cohort. Various learner-centered activities were exploited to invoke active learning. Quantitative analysis was done using credit pass. Pretest credit pass was used as the baseline to be compared with the credit pass to measure the effectiveness of the learner- centered methods on Science Double Award (Biology) performance. Study findings revealed that the learner-centered approach increased the overall academic performance from **28 %** to **36 %** credit pass showing a value addition of **+ 8.**

**Keywords:** *Leaner-Centred Approach, Academic Performance, Multiple intelligence, Learning styles, Inventory test*

## Introduction

Botswana aspires to be a knowledge based economy that promote the use of science, technology and innovation in the socio-economic and business spheres. It therefore calls for an increased number of science students at secondary schools who will pursue science related careers (Presidential Task Team, 2016). Like many countries faced with increased unemployment of young people, the government of Botswana encourages the youth to venture into commercialization of their innovative projects: becoming self-employed after graduation. However, the requirement that all students do science learning areas needs a fundamental reevaluation. Currently most students register for the Science Double Award and more than 90% of those registering for this subject in Form 4 fail the subject. Surprisingly, those that pass are the ones who drop to Science Double Award (SDA) having originally registered for Triple Science. According to the Ministry of Education the results for Botswana General Certificate of Secondary

Education (BGCSE) Science Double Award are an indication that there is a likelihood that the large majority of students fail this subject and thus miss the chance to pursue science related careers (Ministry of Education, 2015).

Botswana Education and Training Sector Strategies Plan (2015), stipulate that Botswana wants to improve the quality of education by transforming teaching and learning. This means changing the teaching strategies to be more student centered coupled with using modern Information and Communications Technology (ICT) at all levels. Qualities crucial in this regard are professionalism, competency, and subject content knowledge and ICT skills. Additionally, conducting relevant and high quality research is a far-fetched approach. Above all, teachers are expected to assist students to improve their performance in the sciences. Unfortunately, one of the biggest challenges faced by teachers is lack of resources which hinder them to efficiently teach Biology.

Nevertheless, the innovative teacher should utilize the ICT skills he or she attained during training to develop learning aids appropriate for both the syllabus objectives, learning styles and multiple intelligences for a given class. The teacher’s role is to create an environment where the learner is motivated to learn: inclusive of provision of content, resources and organization of learning activities. Moreover, the educator has to inculcate positive personality traits that engender good character in both the teacher and the learners for this outcome based approach to manifest.

**Abbreviations**

| | |
|---|---|
| Botswana General Certificate of Secondary Education | BGCSE |
| Education and Training Sector Strategies Plan | ETSSP |
| Information and Communications Technology | ICT |
| Science Double Award | SDA |

**Statement of the problem**

In Botswana, teachers decry the poor performance of Science Double Award and ascribe it to constraints of teaching large under-resourced classes. As a result, they use teacher centered methods in order to curb the problem, but they are continually demotivated because the traditional routine impede desirable results. Astonishingly, Kagiso Senior secondary school has small size classes coupled with disciplined, optimistic students providing an opportunity to utilize outcome based learning. Hence the need to assess the impact of learner-centered teaching in their performance.

**Significance of the study**

The purpose of this study is to investigate the effectiveness of using the limited available resources in delivering student centered teaching of Science Double Award (Biology) with a unique approach of taking the characteristics of learners in cognizance.

## Literature Review

Professional development of a science (Biology) teacher has a significant contribution to the realization of the Biology syllabus objectives and an upsurge in the credit pass of Science Double Award learners. The competency of teachers to reflect upon practice, employ appropriate teaching strategies and activities is a dire need; especially for a teacher to remain relevant in teaching Biology in the 21$^{st}$ century. Capability of teachers is maintained by continued professional development for teachers; despite being graduates, they should be continuously trained on how to use interactive teaching methods in order to cope with the constantly changing information (Tsheko, *et al*. 2009).

Teacher's role is integral in outcome based education as a facilitator, monitor and not a director or dictator. The constructivist educator's responsibility is to create a context where learning objectives are attainable. Learning outcomes are clear statements of what the student is expected to achieve and how the learner is expected to demonstrate this achievement as a result of engaging in the learning process. Research findings postulates that students learning via collaborative activities exhibited significantly greater gains in their abilities to interpret data and apply scientific concepts to novel situations. Results echoed by other researchers in other studies supports that such learners had increased problem solving capabilities.

Competency of teachers is to reflect their practice and implement appropriate student-centered method which is commonly referred to as outcome based approach. In this perspective, the teacher is only a facilitator and the learners are even co-responsible active makers of knowledge, being presented with real-life problems in a collaborative and social environment. The learning environment is no more limited to the classroom, the workplace and home (Auwal, 2013). In the learner- centered approach, the learning process is also preparing the learner for the lifelong learning.

Implementation of learner-centred strategies include active learning, cooperative learning, and inductive learning. In active learning students solve problems, answer questions, formulate questions on their own, discuss, debate or brainstorm during teaching lessons (Kyriacou, *et al* 1999). In cooperative learning learners work in teams and assist each other.

Various learner centered activities that the Biology teacher can use vary from reading to role playing. Reading about a selected topic on the internet and discussing it with other learners together with the teachers enhances independent studying. Searching for and presenting a real world example on a selected topic enriches curiosity (Prasad, 2005).

Solving a real problem, searching for the required knowledge, inquiring from experts and reporting about the solution cultivates research skills and learning how to work independently ("Concept to classroom", 2004). Reporting via an essay by watching a video and summarizing what the learners have learned encourages retention of information. In addition, students could participate in group discussions and present their work collaboratively: students think for themselves, remember what they learnt and also aids in developing communication skills (Tsheko *et al*, 2009). Consistently giving student's quizzes and assignments aid in the diagnosis of misconceptions which are cleared through organized remedial teaching. Significantly, the above mentioned activities help learners with grasping theoretical concepts.

Moreover, there are learning activities like performing experiments and analysing data that equip students with experimental techniques examined in the practical paper which also enhance understanding of the subject content. Projects, problem solving, Olympiad and quiz competitions are essential in inspiring learners and are offered at the Math's and Science club. Skills and knowledge acquired enable the young scientists transcend into exceptional self-motivated and independent learners. Subsequently, they get credit pass grades (A* A*, AA, BB, and CC) in the final examination. All these learning activities need to be varied using different learning aids in order to achieve the intended outcomes.

As a science educator, it is fundamental to fathom the significance of diversifying the teaching materials. A lesson is only as effective as the material used to teach it; there is need to consider a number of factors such as the lesson objectives and the distinctive characters of the students in the class. Learners have varying learning styles and multiple intelligences which the teachers need to integrate in teaching, therefore educators have to provide the students with a learning inventory to determine the learning style and use this information to influence material development. Mc Guire (2018) believes that visual aids for learning have a huge impact on how students retain information; while words can be abstract and hard to retain, visuals tend to be more concrete and easier to recall. Also Aguisiobo (1998) restated that students interacting with teaching aids do not have a blank mind but a consolidated and developed library of knowledge.

Afterwards, a delivery method is selected considering how the teacher want to present the material. As an innovative teacher, techniques to integrate technology should be sought because, it increases student curiosity in learning. Furthermore, Jimoh, M.F. (2009) expressed that advances in technology have brought instructional materials especially the projected and electronic materials to the forefront as the more radical tools of globalization and social development which have affected class teaching situation positively. Such technological breakthroughs like audio-visuals material are an important land mark in knowledge transfer and high academic performance.

## Multiple Intelligences

Intelligence is defined as an all-purpose ability to do well on cognitive tasks, to solve problems and to learn from experience. Robert J. Sternberg developed the triatic theory of intelligence which enunciates that intelligence comes in multiple (especially three) forms which a 21$^{st}$ century innovative teacher must possess (King, 2011). Analytical intelligence is the ability to analyze, judge, evaluate, compare and contrast. Moreover, creative intelligence is the ability to create, design, invent, originate and imagine. Practical intelligence is the ability to use, apply, implement and put ideas into practice (King, 2011). If a teacher possesses all these he or she can go a milestone in identifying and incorporating the diverse multiple intelligences of the learners in teaching effectively.

The multiple intelligences go beyond learning modalities, as they deal with the way information is processed and how learning occurs in individuals. In 1983 Howard Gardener first suggested the seven distinct intelligences as stipulated by King (2011): linguistic, logical-mathematical, spatial, musical, bodily kinesthetic, and interpersonal intrapersonal, existentialist and naturalistic.

Gardener explained that within his theory each intelligence resides in separate sections of the brain. They are independent of each other and exist as single entities without control from any other intelligence. However, each individual student has a separate set of intelligences unlike those of others (Malthy, *et al* 2010). For example, two students might have logical mathematical intelligence, but one might be good with theoretical mathematics while the other might be good with real world mathematics and applied statistics.

It is crucial to keep in mind that the multiple intelligences are problem solving capabilities therefore, students should be allowed to use all the intelligences to solve a problem. Having multiple ways to solve a problem is beneficial for both teachers and students, particularly when problems are complex and require innovative thinking.

## Learning Styles

Just as students have diverse multiple intelligences they also have different ways of learning (Slavin, 1997). Learning styles are found within Nel Flemings VARK model of student learning. These are

1. Visual learners who learn by seeing
2. Auditory learners who learn by hearing
3. Reading/Writing learners who learn by reading and writing
4. Kinesthetic who learn through body movements

The student preferred styles guide the way they learn. They also change the way one represent experience and the way they recall information.

Research shows that each learning style uses different parts of the brain ("Learning Styles,"2019). Students preferred learning styles should be matched with appropriate learning activities and learning aids.

## Learning Aids

Visual aids for learning can also expand beyond the realm of just classroom posters, photographs, charts, pamphlets and creative presentations like PowerPoint, videos and educational infographics. The teachers can enhance documents like research reports, class performing tools and lesson plans (McGuire, 2018). Since Biology involves learning about organisms and nature- objects, specimen, models, botanical garden, an aquarium or fish pond, and industries are one of the useful gargets in learning.

Educational infographics can be used to simplify complex information and be helpful for students who have difficulty remembering information. In data visualization colour plays a bigger role than just for decoration. Further a creative presentation template can go a long way to keep students from sleeping in class (McGuire, 2018). Presenting information in a creative and visual stimulating way help get students excited about a topic. When using PowerPoint, music can be added to entice the musical /audio student. In addition, when a teacher supplements his or her teaching with some video film it is referred to as video-aided teaching. Advantage of utilizing videos is observed when teachers have full control over equipment (Prasad, 2005).

Other forms of learning aids like specimen can be a sample or small piece of the real object. Even a tiny piece of real object simulates interest in students to learn more. Models are imitations and replicas of any original object and are very effective as they are a short cut to understand a complicated concept (Prasad 2005).

According to Prasad (2005) students respond better about any theory they have learned when they see how it works in the real world. Field trips and study tours should be arranged in advance and later must be followed up by a discussion or report to retain information gathered. They are useful because above all, they provide learners with cultural experience available in no other way (McCombs & Whistler, 1997; Engelbrecht, 2000).

**Personality Traits**

According to King (2013 personality is a pattern of enduring, distinctive thoughts, emotions and behaviours that characterize the way an individual adapts to the world. Also, Maltby *et al.*, 2010) points out that, it is the difference in personality that are important for social interaction which is also a requirement in a classroom setting as it directly affect acquisition of knowledge. Personality comes in varying facets which are described as personality traits.

There exist a five –factor model in which psychologists agree that five super traits may adequately describe the structure of personality which was created by American personality researchers Costa and McCrae who measured personality with their well-known Openness, Conscientiousness, Extraversion Agreeableness and Neuroticism categories (Maltby *et al*.,2010).

Openness refers to the trait of having an openness to new experiences and includes characters of showing intellectual curiosity, divergent thinking, willingness to consider new ideas and active imagination (Maltby *et al.*, 2010). Conscientiousness according to (Maltby *et al*., 2010) describes our degree of self-discipline and control shown by individuals who are determined, organized and competence, dutifulness, order, and achievement striving. Extraversion is a measure of the individual’s sociability indicated by individuals who are sociable, energetic, optimistic, friendly and assertive (Maltiby *et al*., 2010). Students with this attribute are supportive and cooperative whereas such teachers can diagnose and address unbecoming behavior (Meador, 2019). Extraverts are passionate and enthusiastic making them to be persuasive, thus winning the audience appreciation (Meador, 2019). Agreeableness is a factor that relates to character of an individual that are relevant for social interaction revealed by attributes such as trusting, empathy, and respectful (Maltby *et al.*, 2010). Neuroticism measures emotional stability and personal adjustment. Individuals with low score experience anxiety, depression, vulnerability, self-consciousness and hostility. (Maltiby *et al.*, 2010).

Discoveries made have indicated that personality is as an amalgam of inner and external traits assimilated over a period of time. Therefore, personality grows over-time and can be developed either positively or negatively (Meandor, 2019). In the context of learner centered teaching, a cruel or a dispassionate teacher creates a toxic environment filled with negativity and underachievers. On the contrary an inspirational teacher creates optimistic students who are able to embrace the toughest challenges even in life (Adapting Instruction, 2019). In this regard, it is important to highlight that most classroom problems are people's problems, hence one requires insights into human behavior in order to teach successfully. Indeed, the personality of both the students and the teachers augments the overall classroom effectiveness that leads to the success of student- centered teaching.

## Study Objectives

### Main Objective

1. Assess the impact of learner -centered approach on the academic performance of Science Double Award biology students.

### Minor Objectives

2. Deduce the multiple intelligence and learning styles and personality traits of students.

3. Plan and teach using varied teaching methods incorporating information from learning styles, multiple intelligences and personality traits for each cohort.

4. Compare and contrast initial credit pass and final credit pass within and among the four cohorts.

## Research Methodology

### Research Design

This study utilized both a qualitative and quantitative research approach to investigate the effectiveness of learner- centered approach in teaching Science Double Award Biology students in Kagiso Senior Secondary school in south east region in Botswana.

### Population and Sample of the Study

The sample of this study comprised of 75 students doing Science Double Award Biology at Botswana General Certificate of Secondary Education (BGCSE) level from the school's enrolment of population of 979 students (524 Form 5 and 455 Form 4). The cohorts were the classes in which they belonged in the school each the biggest in size having 29 students and the smallest having 14 students. The study was spanning for a duration of 3 months. Convenience sampling was utilized to use the available time and resources in the school. Each cohort belonged to a timetabled class in the school.

## Research Instruments

Multiple research instruments were used to collect data including inventory tests, face to face interviews, inventory tests and monthly tests and examinations. Learner inventory assessment was done using inventory tests to determine learners' multiple intelligences, learning styles and personality traits.

Students were taught biological content using various learner- centered methods such as group discussions, experimental work, research and presentations. Quizzes and assignments were administered after each topic and proper remediation offered.

## Data Analysis

Analysis of Biology Science Double Award performance by credit pass was calculated for every test and examination written. It was then compared with the pretest credit pass (used as the baseline) to measure the effectiveness of using varied learner- centered methods. In order to actively involve students in monitoring their progress, they used the performance tracking tool by plotting a graph and calculating value addition. In this context students set their own target mark.

An evaluation form was designed to evaluate the learner-centered method. Interviews were conducted to determine outcome evaluations.

## Results

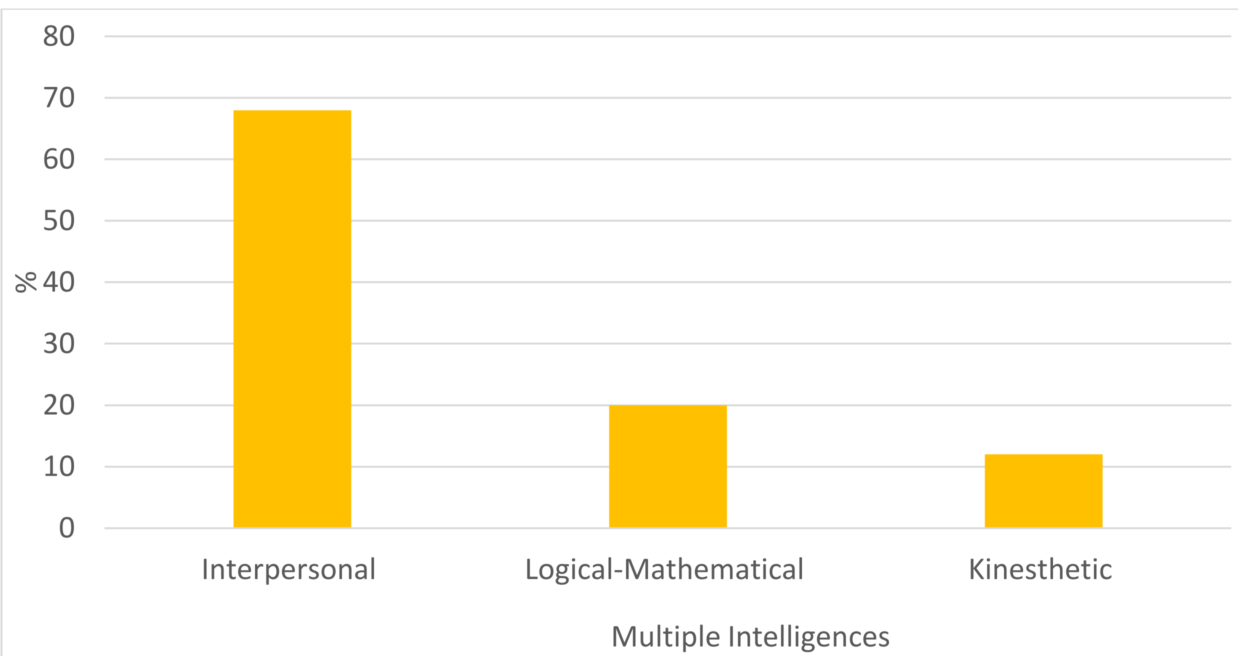


Figure1 indicating the prime multiple intelligences as interpersonal

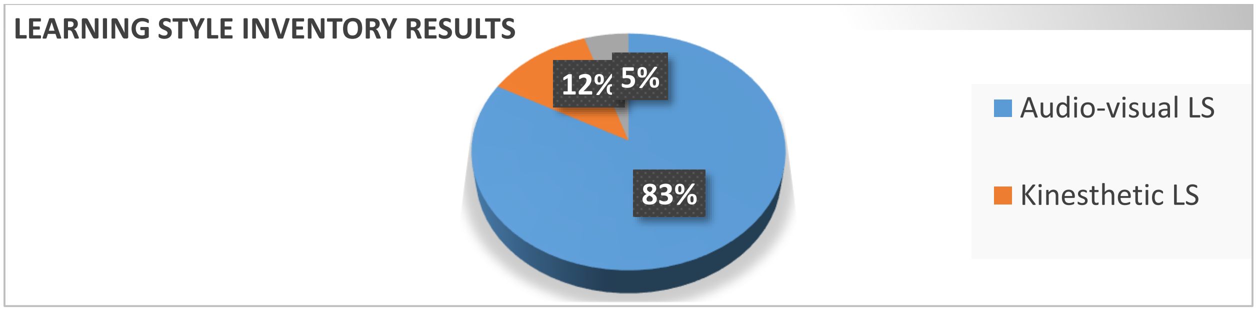


Figure 2 showing the predominant learning styles being audio-visual

Table 1 showing credit pass and value addition increase for all cohorts except for cohort 4

| Cohort | Pretest Credit Pass (%) | Final Credit Pass (%) | Value Addition |
|---|---|---|---|
| 1 | 0 | 8 | +8 |
| 2 | 6 | 41 | +25 |
| 3 | 27 | 47 | +20 |
| 4 | 78 | 47 | -30 |

**Comparing the Progressive Performance across the Cohorts**

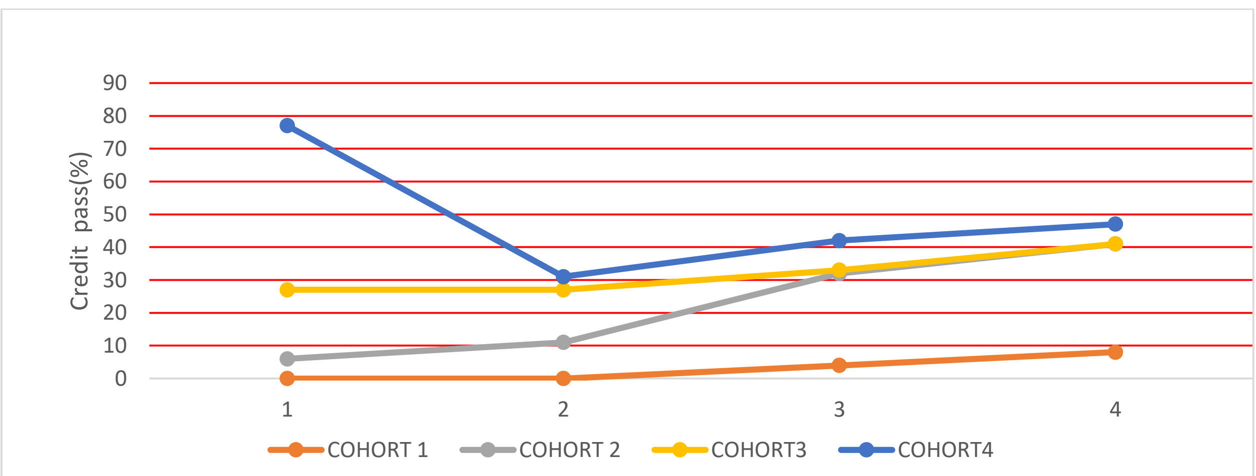


Figure 1 showing an increase in credit pass above the initial for all the cohorts except for cohort 4.

## Discussions

### Qualitative Analysis of personality traits for all the Cohorts from Pre-study interviews

The majority of students from all the cohorts expressed that they are capable of excelling in their studies but lamented that the personality of a teacher hinders active participation during lessons. Desirable qualities they admire in a teacher are caring, respect and fairness. Studies correlate with data as teachers are the second highest determining factor in the development of learners after parents. Findings show that teacher positive attitude have positive effects on student's performance and personality development of students Ulogo *et al*, (2011).

Effective teachers demonstrate professional responsibility by going to class organized Aranas, (1985), are readily accessible outside class(Zhang,2004) and devoted to and answerable for student academic performance (Liu &Meng,2009). They offer fair assessment, conduct ongoing reflection on their experiences and are interested in continuing their own professional development (Minor, Onwue, Witcher, & James,2002).

### Qualitative Analysis from learner inventory tests for Cohort 1

From the interviews conducted and the findings from the inventory tests, the majority of the learners reported that they were slow learners as indicated by their 0% credit pass from pretest results. In addition, they indicated that students prefer lessons conducted in a laboratory because various learning aids were used which helped them comprehend complex information.

In addition, from the inventory test, the researcher discovered that 85% of the students possess interpersonal and linguistic, and visual-spatial intelligences. Only 5% were logical- mathematical and bodily-kinesthetic intelligent. Taking these into consideration student's activities used included group discussions, reading and drawing diagrams. Colourful charts, photographs, models were used frequently to ignite curiosity among these learners. Furthermore, to cultivate other intelligences like bodily kinesthetic and logical mathematical intelligence which was deficient in this cohort, group practical and, plotting graphs activities were given.

As a result of this intervention coupled with the high level of enthusiasm of the teacher, the level of interest in learning Biology increased resulting in increased performance. Madsen, Stanley & Cassidy (1989) asserted that there is a relationship between the intensity of enthusiasm and effective teaching. A teacher who demonstrates enthusiasm is more likely to motivate students (Lowman, 1994). Also having scored high on agreeableness personality trait (85%) helped them adhere to new standards and procedures set by the teacher. These results correlates with those found by Baeten et al. (2010); using learner centered learning environments stimulate deep approaches to learning provided students with extrinsic motivation.

### Qualitative Analysis for Cohorts 2

Results from the multiple intelligence inventory test displayed that 18% of learners in cohort 2 exhibited linguistic and interpersonal intelligences while 11 % are audio-visually intelligent. Surprisingly the majority (77%) of the learners have intrapersonal intelligence thus are quiet and enjoy working alone. Only 1% are kinesthetically intelligent. Prevailing learning styles revealed were 74 % reading and visual and 3% kinesthetic. Prevalent personality trait is agreeableness with a measure of 81 %. Astonishingly the majority of them are timid even when exposed to exciting learning aids. During interviews there were reticent making it difficult to strategize and help them maximize their performance. Nevertheless, the researcher continued using varied teaching methods to cultivate intelligences deficient in the cohort. In addition, it has been found out that of the Big Five personality characteristics, agreeableness was the only factor that significantly correlated with student ratings of instructional quality (Kneipp, Kelly, Biscoe & Richard 2010). High scores of agreeableness of students coupled with that of the researcher helped raise the academic performance. Evidently, Simonton (2003) also reported that behaviors related to the Big-Five personality traits were the key to success, and agreeableness was associated with great teaching. On a positive note, the academic performance of the cohort improved.

**Qualitative Analysis for Cohorts 3**

Results from the inventory tests displayed 80% of learners from cohort 3 exhibiting a combination of bodily-kinesthetic, interpersonal, visual-spatial and linguistic intelligent while only 10% possess naturalistic intelligence. Findings reveal that 89 % of learners have a style of learning that is an amalgam of audio -visual and kinesthetic learning styles whereas 11 % are reading and writing learners. Personality traits range from 70% agreeableness to 50% extraversion. Cohort 3 learners are the only ones with a wide range and learning styles, multiple intelligences and personality traits. In a study conducted by (Abidin M.J.Z et al, 2011) it was found that the high, moderate and low achievers have a similar preference of learning in all learning styles.

Chuang-Chong (1988) maintains that most students favour to learn in particular ways in each style of learning contributing to the success in retaining what they learnt. As such, studies approved concluded that students retain 10 % of what they read, 26% of what they hear, 30% of what they see, 50% of what they see and hear and 70 % of what they say and 90 % of what they say and do. Academic performance in this cohort increased with a high magnitude because the students have diverse multiple learning styles so they tend to gain more and obtain higher grades compared to those who rely solely on one learning style. Also, because of their varying multiple intelligences they had eclectic problem solving capabilities. Personality traits scored at higher levels in this cohort were agreeableness and extraversion. Learners in this cohort demonstrated uniqueness in qualities that contributed to the academic excellence. A high level of extraversion pave a way were for positive evaluation and constant improvement in the delivery of outcome based approach.

**Qualitative Analysis for Cohort 4 (the anomalous result)**

Surprisingly Cohort 4 consisted predominantly of 90% of students with a combination of intrapersonal, bodily- kinesthetic and logical mathematical intelligences. Most of them (78%). learned better through independent reading and individual experiments. Personality traits reflected by results are 64 % agreeableness and 37% extraversion. Generally, cohort 4 had high initial credit pass though it drastically dropped and raised again. Even though the learners were at an advantage of excelling because of their variable multiple intelligences and learning styles there were limited by the availability of instructional materials and resources to effectively achieve outcome based education. Unfortunately, their performance was limited because they do not have textbooks that they read at home. Even the library is not equipped with sufficient Biology books and revision books for reference and for independent study. It is crucial to note that all the learners in all the cohorts do not have textbooks but they were not affected at the same level due to the differences in their learning styles and multiple intelligences.

Correlating with other studies, Inyang (1997) commented that science education programs cannot be taught effectively without the existence of equipment for teaching (Lance *et al*,). The reason being that instructional materials help those who learn to develop problem solving skills and scientific attitude. Elucidating on the same point, Todd & Kulkthan, (2005) confirmed a correlation between the presence and the use of library materials by students and teachers with better performance. Each student will be able to learn at his or her own pace thus the overall results is that students will perform better. Furthermore, Adeogum (2001) revealed a strong positive link between instructional resources and academic performance. According to Adeogum (2001) schools that performed better were schools that have more instructional resources. Therefore, it can be concluded that the academic performance of students in cohort 4 dropped initially because they do not have individual instructional materials.

**Graphical Comparison of the Credit pass for Cohorts 1, 2, 3, and 4**

With reference to Fig 1, for all the cohorts there was a gradual increase in credit pass from the pretest credit pass except for cohort 4. Academic performance for cohorts 1 and 3 was constant at the beginning of the study but then increased steadily. For cohort 2 here has been a gradual increase from the beginning to the end of the study. A peculiar trend was detected for cohort 4 whereby initially there was a drop in performance but during the course of the study the performance was raised to the end of the study. All the cohorts at the end of the study recorded a gradual increase in the credit pass proving that learner centered methods increase the academic performance of Science Double Award learners. This correlates with other research reports indicating that active learning-based teaching methods such as small group discussions, experimentation and outdoor activities are more effective than traditional methods in improving students understanding and their academic performance (Muilifa, and Kapenda, (2017).

## Conclusion

Based on the study findings, it can be concluded that the learner-centered approach has an impact on the academic performance of the science double award Biology learners in a positive way; as the credit passes of all the four cohorts increased when they were taught using learner centred methods. The varying patterns of credit pass reveal that student centered methods effectively increase academic performance with different magnitude and time frame because they work in relation to learning styles, multiple intelligences and personalities. It is important to realise that a class of learners consist of numerous combinations of the above factors. Moreover, Auwal (2013) stipulates that information learnt by scholars is greatly influenced by the way they are tutored. Therefore, each class is unique and will respond effectively to the learner-centred methodology at different rates. Inventory tests are crucial in revealing the individual intelligences and learning styles thus enabled the researcher plan for lessons systematically and produced an intended outcome.

**Recommendations**

1. Inventory tests may be conducted immediately when students enroll to diagnose their learning styles and intelligences prior to teaching. Performance tracking tools should be used by students to track their performance.

2. Universities and colleges of education should train teachers on how to effectively teach using learner- centred method as part of professional development of teachers.

3. Teachers should be encouraged to use audio-visual aids in order to enhance the interest and motivation of the students and keep them attentive in class. Active participation in class and adopting instructional materials participation.

4. Special funds and grants may be reserved for provision of latest audio-visuals, cameras and laptops for teachers to develop learning aids applicable to their locality to facilitate student- centred method.

5. Proper use of audio-visual aids is a skill that teachers may be trained to use, as well as new technology based aids through pre-service courses and in-service teachers' professional development courses to enable teachers to apply the student -centred method effectively.

6. The school library should be upgraded with up-to-date reference materials and revision books to encourage independent study and prevent students relying entirely on the teachers.

7. Departments should organize workshops within the school for teachers to share knowledge and induct each other on delivering learner-centered approach effectively. Workshops, seminars, conferences or orientation courses on Biology should be designed to acquaint teachers with the latest developments in the field of Biology.

8. Well-equipped laboratories with mounted projectors and smart boards connected to the internet should be established in all schools to enable students to use interactive devices that enhance learner-centred learning.

9. Each school should establish a botanical garden, fish pond for learning biology and organize educational field trips and tours to relevant places to expose students to the real world so as to make discoveries on their own.

11. All schools should have functioning Maths and Science Clubs and members should participate in science fairs.

12. If schools want all students to be excel, they must use a broader range of activities and reward a broader range of performance than they had in the past.

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**Article 5**

# Teacher professional development: Equipping science teachers with necessary constructivist classroom skills

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**Abstract**

The study of pedagogy aims at increasing opportunities for learning by students at every teaching episode. Movements range from constructivism, which believes that children's prior knowledge and misconceptions need to be addressed for learning to take place, to argumentation, for cultivating scientific reasoning in students. In this paper, two purposefully chosen classes were given different treatments on a topic at the junior secondary school level. One treatment was a constructivism learning environment while the other was a traditional normal teaching lesson. Results show that whilst the teacher was a qualified science teacher with many years of experience, the partnership with the science education specialist was fruitful. Chronbach's Alpha gave a reliability value of .764 with a near medium effect size ($\omega^2$) of .053. The traditional class (MH2), performed significantly lower than the constructivist class ($F_{(1,84)} = 4.702$; $p = .033$) overall and also on question 2 ($F_{(1,84)} = 9.375$; $p = .003$). Whilst the science teacher was willing to adapt to the new and different way of teaching, there were challenges nevertheless. It is suggested that professional development activities need to pay more attention to teacher needs than perhaps the traditional route of paying more attention to student performance.

**Keywords:** *Professional development, science teaching, constructivist teaching, traditional teaching*

## Introduction

The debate on the best methods for preparing teachers as well as what qualifies a teacher as a good teacher is an old one (See Suping, Mokgothu & Garegae, 2012). Suping (2014) for example, makes a case for a training of in-service teachers that allows for positive deposits to be made into the teachers' pedagogical content knowledge accounts with a view to giving them a deep understanding of the topics under discussion. He concludes his work with a question that casts doubt on the optimisation of training for science teachers in Botswana. What level of training, Bachelorette or Master's level is optimal for effective teaching at the secondary school level? On a related matter, Green and Rollnick (2006) discuss what they call the structure of the discipline, the thing about a discipline that makes it different from other disciplines and inherently somewhat contributes to its difficulty or lack thereof. Training a teacher, a science teacher for example should as a matter of fact also involve training such a teacher to have an appreciation of this specific characteristic of the discipline.

Professional development assumes that the teacher has the necessary pedagogical content knowledge attained through training and attempts to address the shortfalls that may have occurred during training. But both the assumptions of what actually transpired during teacher training as well as the resultant professional development activities seem to miss the target. Consequently, Koosimile, Suping and Motswiri (2018, p. 64) quipped:

[The] current overarching framework of teacher training and development in Botswana, comprising mainly pre-service and in-service sectors with each canvassing its own priorities and sensitivities, with the expertise for interpreting, interrogating and engaging on issues on STEM lying elsewhere with experts, is unsustainable and needs rethinking as it seemingly lacks relevance and capacity to prepare STEM teachers for globalized and knowledge-based economies in the 21st Century. The framework is rigid, has a restricted and introverted scope for each sector, and is not responsive enough to empower and capacitate teachers to own, define, explain, and drive not only their professional development, but also their research on teacher practice in line with emerging global and national priorities in STEM

The paper described attempts by authors at addressing shortfalls in both pre-service and in-service teacher training and development in the STEM areas. In this case such attempts were made under restrictive formal schooling environments where such teachers were students in a formal university setting. Divergently, this paper describes in-service activities in a semi-formal setting where collegiality as opposed to teacher-student nexus prevails. It reports on a partnership activity where a science teacher worked with a science educator on a professional development activity based on a mutual understanding of both. Thus it is hoped the shortfall alluded to by the paper by Koosimile et al (2018) will somewhat be addressed as the teacher, the practitioner is also empowered by the partnership.

Both authors are passionate about science education and are as concerned as the rest of the country is about the continued decline in performance by students in the STEM subjects in national examinations. In fact, both are members of a Ministry of Basic Education (MOBE) taskforce working on developing interventions aimed at addressing such declines nationally by looking into appropriate professional development activities for the mathematics and science teachers across all levels of education.

Specifically, the paper will seek to address the following research questions:

- Can the type of teaching activities determine student performance?
- Do science teachers also need help reaching their students?
- Can partnerships with University teacher science educators help science teachers?

## Methodological considerations

The study employed an experimental design (Cobb, 2000) where the classes used were purposefully chosen by the researchers. Purposeful since real classes in a real school setting taught by a real teacher were used. The aim of the study therefore is not to generalize to any population but make reference to the classes taught (Keppel, 1991). Two out of possible six Form 2 classes, one with 41 students and the other with 43 were chosen for the study. Whilst a third control group was desirable, it was left out for the simple reason that the authors were also going to study each other. One class (MH2) was taught using the traditional teaching commonly used in the school that could be best described as teaching science in highly theoretical fashion. In this teaching, there are no experiments done, any science equipment made reference to, students are not even shown pictures of same. A fuse for example will be mentioned and its symbol in circuit drawn on the board. None will be brought to class, not necessarily because the school does not have one, but because it is what teaching has boiled down to.

In the other class (ST2), both authors prepared a lesson that could best be described as constructivist in that it was not only designed to engage students mentally but also demonstrated the concepts as well as necessary equipment used for teaching the concepts. For example, actual circuits were used in demonstrations and students got to see the effects of the manipulation of the different variables. A constructivist classroom here is as conceived by Tobin, Tippins and Gallard (1994). Both classes were double lessons of 80 minutes duration.

The teacher was new to the constructivist teaching method and consequently also became the subject of study. On the other hand, the researcher as participant in the study was to also become a subject of study by the teacher. This was important to attempt to address issues of power in the research collaboration. None of the authors had authority over the other but were equal partners in journey of professional development.

The "achievement of the delicate balance between participation and observation" (Angrosino & Mays de Pèrez, 2000, p. 674) therefore had to be negotiated by both authors, albeit from different perspectives. Whether this is truly possible to achieve is left to the reader but the authors will be quick to acknowledge possible biases based on the proposal that there are two methods proposed with one potentially being better than the other.

After the classes were taught, both classes sat for a teacher constructed test on the unit taught at the same time in the afternoon to avoid contamination of result should the different groups sit at different times. The tests were then graded and results subjected to statistical analysis using SPSS 25. Means were computed and compared for both the overall performance as well as on scores for question 2 per class using ANOVA tests at 95% confidence level.

As a background to these results, data from tests done by the classes for the months of February, April, May, July and September 2019 were ran and means compared for the classes using ANOVA at the 95% confidence level.

## Results and Discussions

Whilst the interest was on the performance of the students based on the treatment they received, there was also vested interest in the way the teacher would, not only execute the lesson, but also her disposition to the seemingly new method to her. Interest was also on the second author to determine the first's uptake of their interactions. Because of the second author's relationship with a colleague who they co-teach classes together at their school, the colleague was also present when both classes were receiving their treatments. This arrangement offered a unique window into the thoughts of this colleague though initially not part of the experiment. The results are therefore presented in four overarching categories; the results of the student performances on the topic test, the views of the first author, views of the second author and views of the observing colleague.

### *Student performances*

To provide background to the performances of the two classes over the academic year, test results for the cluster prepared monthly tests for the year given prior to the intervention were compared. Table 1 shows the results of the ANOVA test. The Alpha reliability statistic was .954 over the five tests.

Table 1: F statistic results for monthly tests

| Source | df | SS | MSS | F | p |
|---|---|---|---|---|---|
| February | | | | | |
| Between groups | 1 | 676.378 | 676.378 | 2.956 | .089 |
| Within groups | 84 | 19222.831 | 228.843 | | |
| April | | | | | |
| Between groups | 1 | 172.636 | 172.636 | .619 | .434 |
| Within groups | 84 | 23424.620 | 278.865 | | |
| May | | | | | |
| Between groups | 1 | 114.832 | 114.832 | .319 | .574 |
| Within groups | 84 | 30215.552 | 359.709 | | |
| July | | | | | |
| Between groups | 1 | 44.320 | 44.320 | .134 | .715 |
| Within groups | 84 | 27782.005 | 330.738 | | |
| September | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Between groups | 1 | 88.956 | 88.956 | .348 | .557 |
| Within groups | 84 | 21491.846 | 255.855 | | |

As can be seen from Table 1, for the five months that the two classes wrote the monthly tests, there was never a month that the performances of the two classes were significantly different. This confirmed the earlier claim that the classes in the school were not streamed and so was expected that their performances should be similar.

After treatment, the two classes wrote the same test at the same time under same conditions. The performances were categorized into two streams; overall performance in percentages as well as performance on question two alone. Question two's peculiarity was based on its highly applicative nature.

Chronbach's Alpha gave a reliability value of .764 with a near medium effect size ($\omega^2$) of .053. The traditional class (MH2), performed significantly lower than the constructivist class ($F_{(1,84)}$ = 4.702; p = .033) overall and also on question 2 ($F_{(1,84)}$ = 9.375; p = .003). Table 2 shows the ANOVA results of the analysis. The two lesson presentations were different and the results obtained are not surprising. The constructivist lesson presentation allowed students to experience, first hand, the use of resistors in experimental set-ups. This was not the case with the traditional presentation. It would seem, especially because the classes in the school are not streamed, that the differences in performance can be attributed to the type of treatment.

Table 2: F statistic results for treatment scores

| Source | df | SS | MSS | F | p |
|---|---|---|---|---|---|
| <u>Question 2</u> | | | | | |
| Between groups | 1 | 11.400 | 11.400 | 9.375 | .003 |
| Within groups | 84 | 102.135 | 1.216 | | |
| <u>Overall mark</u> | | | | | |
| Between groups | 1 | 2267.167 | 2267.167 | 4.702 | .033 |
| Within groups | 84 | 40499.635 | 482.139 | | |

Question 2 performance is of interest due to the application nature of the question. In the constructivist classroom, students had had exposure to use of a variable resistor in a circuit, an opportunity that the other group did not have. This exposure allowed more students in the constructivist group to do better (mean = 1.02) than the traditional group (mean = 0.30) out of total possible score of 4. This was made possible with just a demonstration experiment for the students. One can only imagine what opportunities doing class experiments would do.

***Views of the First author***

Fortunately for the study, and a possible confounding factor, the second author is not new to innovations in her teaching. For example, she co-teaches her classes with a colleague in the school and has, together with the colleague, shared topics they teach based on their strengths and comfort levels. Bringing an innovation in her class therefore was not something new to her. She executed the constructivist lesson well despite doing it for the first time and not having seen it demonstrated.

There were challenges however. The traditional lesson went as expected. The challenge was with the constructivist lesson where the teacher was not patient enough to build ideas with the students. For example, the idea of a variable resistor, whilst not mentioned in the syllabus, is critical to some of the application questions found in past examination questions. Question 2 was formatted along the same lines. This idea was not meticulously developed with students but the teacher instead 'told' students both what happened as the resistance of the wire was increased by sliding the resistor in one direction using the demonstration experiment.

The thinking during the lesson planning phase was for students to arrive at the same through observation and propose a viable explanation of the observation and then perhaps even draw a generalisation out of it. This never saw light of the day as the teacher 'gave it away'. It was concluded therefore that the skill of lesson presentation in a constructivist manner is a skill that needs to be practiced, developed and mastered over time. This observation and conclusion are despite the over ten years of teaching experience at the level by the teacher.

It must be noted however that the students were very excited to an extent that some remained after class to play around with the circuit that was set up with an attempt to try and find out how the whole thing really worked. The interest and zeal were not observed with the traditional class. The constructivist class had a very positive disposition to the materials presented and appeared willing to learn more. One student towards the end of class introduced an application to the use of resistors and gave power tools as examples where resistors could be used. This was, more importantly, voluntary on the part of the students as he had not been asked to explain any of it.

***Views of the Second author***

The second author spoke passionately about her love for teaching but bemoaned her dying passion with the passage of time. She recalled her career infancy, when she would read books and prepare extensively for class and how all this has stopped. Teaching now seems to be dictated upon by what the examination body covers than what should be covered as prescribed by the syllabus. Her experiences though having tried this lesson have rekindled her love for teaching. She even feels confident teaching the topic on electricity which she has not liked teaching and would pass it on to her friend to teach.

Strangely enough, the idea of 'giving it too early' to students, even after reflection on the lesson did not surface until the first author brought it up. This thinking was to allow students in the constructivist classroom to process scientific results like scientists. They should make observation and then come up with possible explanation before generalizing or generating theories. Just like the observing colleague, the second author claimed to have learnt a lot from the exercise and had some of the misconceptions she held on the topic dealt with. She felt a new lease of life as far as teaching was concerned.

### *Views of the observing colleague*

The observing colleague maintains she learned a lot from the exercise. She felt that the teacher did a good job in teaching both classes. Despite also having many years of experience, and the fact that she was also present when the preparation and discussions on the constructivist lesson were made, the observing colleague also did not see fault in the teacher 'giving it too early' to the student. She felt that she learnt a lot from the whole exercise and wished that it could be repeated with other topics or opportunities made for them to be workshopped on these practical ways of presenting lessons.

Asked why they do not teach in the constructivist fashion all the time, she was quick to point out that they are under immense pressure to produce good results to the extent that often times they are more concerned with finishing the syllabus than whether or not students understand. Any form of improvisation and use of experimental setups are seen as potential waste of time.

## Concluding remarks

The general view among educators is that teachers as agents of change have the necessary tools to bring about the change needed by systems. For example, Lee and Luft (2008, p. 1344) write that "[as] core agents of reform, teachers possess specialized knowledge that is acquired through years of teaching and professional development experiences. The knowledge that teachers acquire through practice is specialised, much like the knowledge found in other practice-driven professions, such as architecture, social work, and medicine". Whilst this is true, there are always challenges with the conditions under which science teachers work. Resources are limited and often not even available, dictating that teachers need to think outside the box and come up with innovative ways of teaching.

Such conditions as these are environments these teachers would not have been exposed to during training. Adapting and improvisation therefore have to be learnt under workshop condition or other professional development activities which could even be school based. There are other more pertinent views that this study brings to the fore. Does a diploma qualification suffice for a science teacher at the junior secondary level? Would a bachelor's degree do? Perhaps even more importantly, what qualification should the different, especially teachers of the different science subjects, have at the different levels of education if they are to make a meaningful contribution in the lives of the students? Conversely, would enough professional development activities make up for the skills that would be acquired through training during schooling?

Another more salient observation is the apparent inabilities of the teachers to 'see' weaknesses and possible areas of improvements during observations. This observation could be coupled with the teachers' inability to also reflect as practitioners. The second author was given opportunities to reflect on the lesson presentation after teaching. The same opportunity was also given to the observing colleague. Both missed the 'giving it too early' observation made by the first author but upon discussion agreed with the observation.

This brings into question the skill of observation which is very critical in professional development activities. Is this a skill that can be taught? What are the implications of such a skill not developing even after over ten years of experience? These and perhaps many other questions should be addressed in formulating professional development activities that are geared towards empowering the teacher.

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**Article 6**

# A survey on ICT integration implementation: A case of schools in north east regional operations for education in Botswana

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**Abstract**

The paper evaluates the role of ICT integration as an initiative to enhance delivery in the classroom. The use of ICT in teaching-learning although critical, most regions have not yet embraced this initiative. The research targeted teachers of STEM subjects. Schools in North East Region, Botswana have been piloting ICT integration since 2016. Research questions for this study included: How many teachers in a given school are trained on ICT integration? Are the schools equipped with the necessary gadgets to enable effective ICT Integration? The study was a qualitative bench analysis of ICT integration coupled with quantitative analysis on effect of ICT integration in 13 selected schools. Preliminary results from qualitative analysis highlighted that an effective teacher capacity building system improves teacher motivation and self-esteem. The results from North East Region indicated that out of 160 participants from 13 schools, only 75 (46.9%) were trained on ICT integration. Of these 75 trained, less than 30% were using technology in teaching-learning process. Teachers reported that lack of internet was a limiting factor for ICT integration. In-service training was also a challenge. The recommendations from the study is to have enhanced capacity building and working internet connectivity to motivate implementation following training.

**Keywords**: *Capacity building, ICT integration, Teacher motivation, STEM*

## Background

The paper evaluates the effect capacity building for teachers of STEM and impact of ICT integration on content delivery. The study focuses Botswana, Kenya and Zambia. In Botswana, teachers are initially trained in universities and Colleges of Education (CoE) but their induction and CPD has not been part of their continuous work plan while their counterparts in Kenya and Zambia follow a systematic CPD programme. The use of ICT in teaching and learning becomes critical. Research questions included: To what extent is ICT used in classroom teaching? Is the global desire toward building 21$^{st}$ century learning environment being achieved? What is the trend of development on ICT integration in schools? The study is a qualitative bench analysis of INSET systems and ICT integration. Preliminary results of this study highlighted that an effective teacher capacitation system improves teacher motivation and self-esteem. The observations from the schools where Lesson study was conducted in Zambia indicated that with CPD teachers employ themselves to go an extra mile in preparing for STEM lessons making them more interactive. In Kenya, the strengthening of the teaching of STEM subjects coupled with introduction of teaching with technology has been reported to enhance the teaching-learning process.

## Introduction

It is apparent that for a teacher to bring forth quality learner output, they themselves should be carrying a positive attitude, relevant competencies and skills as well as desirable work ethics. This therefore calls for an education system that has mechanism in place to ensure continuous capacity building, that is, a systematic In-service training system. The teaching-learning process requires constant re-tooling to afford teachers to keep up with changes and remain relevant. This include having positive inclined school management, which is a critical and integral component of Capacity building for continuous professional growth for working holistically with all members of staff and students to establish an inviting school environment is imperative (Renchler, 1992). INSET systems should be able to cultivate school-based support strategies amongst the teachers and school management (Duruji et. al., 2014). School-based support is viewed as one of the best moves in an institution and a possible guarantee for sustainable development in education issues.

Although quality training of teachers is one of the big steps towards quality learner output, lack of continuous CPD become a detrimental factor in the education sector. With the advent of 21$^{st}$ century compliance globally, no nation/country's education system should be seen to be left behind in preparing its own teachers and learners to be 21$^{st}$ century compliant. One of the ways to achieve this is using technology in the teaching-learning process. This has been found to enhance effectiveness and efficiency. The introduction of Information, Communication and Technology (ICT) in teaching and learning becomes critical. Developed countries are advanced in this area and so is the quality of their learner output. Various technology aided methods and /or pedagogies have been devised on technology-aided learning. Over the years, relevant technologies have continued to flow to schools as they emerged (Busthami et.al, 2015; Mbalamula, 2016). These include among others use of office 365, power point in learning, ICDL, 21$^{st}$ Century Learning Design (21CLD), to mention but a few. However, to what extent are these technologies used in classroom teaching-learning in developing and middle income countries still remains a question.

A study conducted by Onwuagboke & Ukegbu (2010) indicated that for ICT integration to be of advantage in the teaching-learning process, teachers ought to be effectively capacitated on ICT pedagogical approaches. This approach, according to Onwuagboke & Ukegbu (2010) have been exploited by developed countries that has led to the transformation in their educational landscape at all levels. To prepare the education sector for this task, policies and frameworks should support full integration of information technology in teaching-learning at all levels.

## Problem Statement

For a considerable number of years, the education system has operated without the benefit of a systematic in-service training model, the results of which were that In-service training was limited hence a number of teachers would go on for too long without any training. With lack of a clear INSET structure adopting and adapting the use of technology in learning became a challenge.

## Significance of the Study

This study is meant to review from those countries that have long been using technology aided teaching, with the objective of finding out the impact on content delivery by the teacher, learner retention and learner quality output. The findings from the study will also help inform policy on transformation of education on how best use of technology can be employed.

## Objectives of the study

This study is meant to:

i. assess from literature the effect of the use of teaching with technology on content delivery at general education level of learning (Grade 0 – Grade 12, that is, reception to form 5) in North East Region Schools of Botswana

ii. analyses the effect of teaching technology on learner quality output

iii. assess the impact of ICT integration on teacher preparation and content delivery

## Literature Review

*Teacher Capacity Building*

During the last few decades, there has been a tremendous growth in the use of ICT in all fields such as industries, businesses, societies, lives of people and education (Roy, 2015). ICT have become an integral component of life (Noo-Ul-Amin, 2013). Application of ICT tools in Teaching-Learning Process has changed the total scenario of teaching and learning process (Maitlamo, 2004; ETSSP, 2015; Roy, 2015). Teaching–Learning Process is not now limited within the boundaries of classrooms but beyond and as such, the teacher should be looking beyond the classroom boundaries to cope with these learners and 21$^{st}$ century demands (Busthami et.al, 2015; ETSSP, 2015; Roy, 2015). According to Roy (2015), it is appropriate to integrate ICT application in education as this provides opportunities for both the teacher and the learner to adjust to individual needs during the learning process. ICT has also been considered as one of main factors required by each state to drive economic growth (ETSSP, 2015). This was a move from the Maitlamo Policy of 2004, which emphasized the need for clearly outlined framework guarding, guiding and facilitating use of technology in the teaching-learning process.

It is apparent that global drive toward building sustainable knowledge-based society has made stakeholders of the education industry to recognize the potential need for ICT integration in education (Busthami et.al, 2015). Although a policy on ICT was developed, very little has been achieved. In Zambia and Kenya on the other hand, literature indicates that there has been some significant milestones achived on this area. This has seen Kenya Ministry of Education embarking on establishing STEM schools (Mboya, 2016). A study in Kenya by Dr Tom Mboya (2016) on Inviting School Environment was an initiative to scan the school environment in public schools in preparation for strengthening the use of technology in the teaching-learning process and responding to the global call for embracing equipping learners with 21st Century Skills. This was meant to prepare for initiatives to strengthen capacity building in preparation for STEM learning.

This requires though, every educational system to have in place a clear capacity building structure for the teachers thus the UNESCO regional office for Southern Africa recommendation for a Regional Framework (UNESCO, 2016). According to UNESCO (2016), this framework is meant to encourage every SADC member state should have Continuous Professional Development (CPD) for teacher standards and competencies and taking use of ICT into perspective. These standards, which looks into strengthening teaching profession, are concerned with areas of teacher competencies and professionalism. ETSSP (2015) indicated that “The Information Communication and Technology (Maitlamo) Policy (2004) states that successful integration and sustainability of ICT in the education system requires a supportive policy environment and framework at the national level”. There is a lot of emphasis on the introduction and integration of ICT in learning, professional development of teachers, development and use of relevant content and software as was indicated by Maitlamo Policy of 2004 (ETSSP, 2015). Educators will not adopt a technology where there is no perceived need or productivity gain (Nwigbo & Madhu, 2016), it is on this note that choosing the relevant ICT programme to use in an education system is very important (Mbalamula, 2016). Microsoft Education has come up with a number of initiatives and programmes to help educators and learners to use technology in the teaching and learning (P21 Report, 2004).

According to Noor-Ul-Amin, (2013) argues that the use of ICT in education creates the most wanted learner-centered learning settings unlike the despised teacher centered approaches. This facilitate students to move towards virtual environments through skills, specialized expertise and ability to articulate themselves (ETSSP, 2015; Ali et.al, 2013; Ferreira and MacLean, 2016). Of course countries are making endeavors to recognize the requirement of Sustainable Development Goal 4 (SDG 4), (ETSSP, 2015; UNESCO, 2016) that places importance of professional development as a way of effective content delivery in the 21st century. According to ETSSP (2015), professional development is a process that drives professionals towards lifelong learning. The impact on enhanced teacher skills and knowledge ultimately influences students’ achievement and yields quality learner achievements (ETSSP, 2015; Roy, 2015; UNESCO, 2016).

Langworthy (2013) pointed out that 21st Century Learning Design learning activity rubric that operate through six dimensions, which include; Collaboration, Knowledge construction, Real-world Problem-solving and Innovation, Self-regulation, Use of ICT and Skilled communication insinuate school-based INSET practices that enhance teacher professional growth, a component critical for creation positive school culture.

*ICT Integration Discussed*

Information and Communication Technology (ICT) has three parts that are Information, Communication and Technology. Information is the summarization of data (Roy, 2015; Nwigbo & Madhu, 2016). Communication is a process that disseminate information and Knowledge, and Technology is a mode or media through which information can be disseminated (Roy, 2015; Nwibgo & Madhu, 2016). According to Roy (2015) and Ferreira & MacLean (2017), ICTs have not only revolutionized the way people work in todays' world but is the drive in transforming education systems. New technological tools help in the experimentation and action with the help of the internet and various communication tools (Busthami et.al, 2015; Nwigbo & Madhu, 2016) which implies that transformation of education systems need not to only consider policy formation but also acquisition of the appropriate and relevant infrastructure and resources. ICT includes communication devices and applications like computer, hardware networks, software, mobile technology, satellite communication, video conferencing, RFID Technology, WI-FI zone, pen drives, Internet, www, Web2.0 and Social media, etc (Roy, 2015; Nwigbo & Madhu, 2016). Accelerating technological change is quite evident today and the rapidly accumulating knowledge, increasing global competition and rising workforce capabilities around the world makes 21st Century Skills essential (ETSSP, 2015; Roy, 2015; Nwigbo & Madhu, 2016). According to Nwigbo & Madhu (2016), there is a two-way relationship between ICT and the curriculum where ICT may be used to assist in conveying the curriculum but at the same time may change the content of the curriculum. ICTs provide greater opportunity for both teachers and students to adjust learning and teaching to individual needs (Roy, 2015; UNESCO, 2015). The present high technology and highly competitive society will sustain only through knowledge of Information Communication and Technology (Noor-UI-Amin, 2013).

According to Nwigbo & Madhu (2016) and Busthami et.al, (2015), ICT is said to enable teachers to save time and to increase productivity. ICT has been found to facilitate activities in the teaching-learning process. It allows access to a variety of information sources, forms and types, preparing and updating daily lessons plans, making hard copy visualizations and handouts for classes, as well as individualized educational plans for slower students and students with disabilities or with special problems. It allows presenting visual/oral content materials, tasks, and questions to the audience; maintaining grade books; compiling a data bank of exam questions; inspection and correction of students‟ work on their computers; and keeping records, chronicles, and archiving with the possibility of allowing quick retrieval of the same (Basri et., al. 2018; Aristovnik, 2012). It has a positive effect on behaviour, motivation, communication and process skills of students and teachers (Nwigbo & Madhu, 2016).

It is paramount that teachers adapt to initiatives and innovative teaching methods which are relevant to 21st century learner, there is need for pedagogies and content that will deliver a 21st century learner (Ferreira & MacLean, 2017; Nwigbo & Madhu, 2016). The teacher should must be competent in a broad spectrum, not only on their subjects of specialty but even in the manner they plan for their lessons (UNESCO, 2015). Teaching with technology has been found to bring a connection between virtual world and real-world making teaching-learning process to be interesting and exciting even for subjects viewed as being difficult (Langworthy, 2013; UNESCO, 2016). Use of ICT supports blended learning approaches to improve learning and meet the need for skills development and targeting disadvantaged and marginalized groups so that they can take part in education (ETSSP, 2015; Busthami et. al., 2015; Nwigbo & Madhu, 2016). The use of ICT can also aide in improving performance, teaching, administration and develop relevant skills to disadvantaged communities (Noor-Ul-Amin, 2013). Malaysia recognized the critical role of education as the driving force of its transformation process into becoming a knowledge-based society as a necessary requirement of becoming a developed nation in the information age (Busthami et. al, 2015; Anthony et.al, 2016) using technology in teaching learning.

## Methodology

A systematic literature review following the EPPI-Centre (2007) methodology, comprising the following stages (Jindal et al., 2013).

Data from thirteen (13) schools in North East Region of Botswana, of which three (3) were all the senior secondary schools in the region, four (4) were Junior secondary schools and six (6) were primary schools from North East Region was collected using a survey tool (questionnaire). One hundred and sixty (160) teachers participated in the survey. The data was analysed through simple mathematical procedures with percentage of teachers participated being taken into consideration. There was also qualitative analysis based on responses from participants.

## Results and Discussion

Education intends to impart necessary knowledge, skills and values required in the world of work. In the 21st century, most of the economies of the global world are shifting from resource-based to knowledge-based economy. This calls for a human resource that will be relevant in this digital era. However, many of our schools and/or teachers are still rallying behind with pedagogical methods that are not suitable to support learning in the 21st century. Thus, 20th century teachers, in the 21st century. It is therefore that, teacher professional development is key, to upgrade and develop necessary skills for educators to be relevant in their present time. All the six (100%) primary schools visited were found to have developed policy on Computer Awareness but not ICT integration. The schools though referred to the said policy that is in line with Maitlamo, a Botswana National ICT Policy of 2004 that emphasized on each school developing an ICT Policy/framework and guidelines. Although all schools adhered to the call by developing such policies, out of the six primary schools, only 4 (66.7%) had action plan for ICT, which they indicated that the activities are never carried out due to lack of resources and or training. Even with action plan the teachers that participated in the survey indicated that the plans are not be followed/used. This has resulted in the effectiveness of ICT integration in the schools becoming very low. Those that were trained on ICT integration were lagging in the implementation of the same thus making them forget even what they have been trained on. This is a clear indication of lack of strengthened capacity building and follow-up. The use and impact of teaching with technology in the schools could not be measured. It was evident from the literature reviewed that use of technology in teaching is critical for one to obtain quality output. Total teachers that participated in the survey was 49 from 6 primary schools targeting Mathematics, Science and English. Out of these 26, that is 53.0% were found to be trained on ICT integration. There was an indication from the participants that there were in-house ICT integration workshops that were held at school levels. This was an indication that more are trained in each school. This was shown by the number of teachers that were reported to be implementing ICT integration, that is, teaching with technology that was standing at more than 50% for most schools. Only one (16.7%) primary school from selected reported not to be undertaking ICT integration. There was a clear indication in all the schools that teachers are supported and offered capacity building initiatives through workshops on ICT integration. The lack of internet accessibility in schools where connectivity has been made was reported to be one of the major hitches in allowing teachers to fully integrate ICT in the teaching –learning process. Four (4) Junior Secondary Schools were sampled with fifty-one (51) teachers from Mathematics, Science, English and Social Studies participating in the survey. Thirty-three (33) that is 64.7%, of these participants reported to have been trained on ICT integration. Although more than 50% were trained, less than 30% reported to be implementing teaching with technology citing many challenges, among which were the lack of resources/infrastructure. The teachers engaged with teaching with technology alluded to the fact that teaching has become more interesting and motivating for learners. The participants from senior secondary schools were fifty-five (55) from all sciences, mathematics, design & technology, art, English and Setswana from three (3) schools. Of these participants only sixteen (16), that is 29.0%, indicated to have been trained on ICT integration but have not cascaded the training to others. This has negative impact on implementation as all the schools reported to be doing very little on ICT integration. It was only one school that indicated that its ICT integration team has been resuscitated and was re-organizing the teaching staff in terms of having organized ICT integration training and implementation. Different authors, although most discussing ICT integration in general, confirmed that the use of any technology-assisted programme, of which 21CLD is one of such, in the teaching/learning process is key to quality learning. Roy (2015), Busthami et. al. (2015); Nwigbo & Madhu (2016) in their studied found out that use of ICT/technology in teaching and learning lead to change in attitude in the teacher, learners and shape the education system to drive economic growth.

Teacher capacity building proves to be critical to enhance the learning process and to deliver a 21$^{st}$ century learner which are sentiments also indicated by Langworthy (2013). Most of the schools did indicate that there are getting very minimal support from the capacity building designated officers from the region. All the four (4) schools supplied with tablets indicated that the tablets were of low memory and could not upload many applications that have been identified by teachers as useful in the teaching-learning process at primary level. The computers in the junior and senior secondary schools were reported to be mainly setup for learners doing Computer Awareness and as such, it was rarely available for use by other teachers for other subjects. To produce high quality and immensely competent teachers who keep up with emerging and current concepts, there is need for institutional strategies that improve learning in the 21st century world and thus the 21 CLD is very ideal in achieving such as also stated by Langworthy (2013).

To deliver a 21st century learner educators need to embed 21 CLD into the pedagogy and this calls for innovative teaching. Innovative teaching support methods that engage learners more. In this regard, educators are no longer the source of all knowledge, but rather incorporate pedagogical methods that cultivate learners' understanding ability and empower them, a point emphasized also in the discussion by Langworthy (2013).

In enhancing content delivery, 21CLD enables teachers to blend content knowledge. Critical thinking, problem solving, communication and collaboration are a necessity for educators to promote an understanding for every learner. As indicated by Langworthy (2013) teaching with technology enables the teacher to use appropriate learner-centered methods that will help learners to own their learning, hence apply well what they have learnt. It requires that educators be active and engaged knowledge-builders, adopting and using the very skills they are seeking to instill in their students. From the survey, it was reported that the schools do have ICT integration teams that are responsible for helping teachers with organised computer awareness schedule for learners. Only 2 schools reported that the team is responsible for running ICT integration activities. Of the six (6) primary schools sampled, one (16.7%) was found to have a fully-fledged ICT hub and as such the teachers alluded to the fact that teaching has become more interesting and motivating for learners.

It is worth noting that support systems are not merely ends but means to a greater goal as they help children develop cognitive, academic and physical competencies they need to succeed in 21st century life. Effectively, the nucleus of quality education in this regard is innovative teaching. Innovative teaching calls for robust professional development that involves teachers to be directly engaged in practices, it is quite imperative that teachers research on new teaching pedagogies. Teachers have to adopt these comprehensive, coherent and integrated new practices. As such, it is significant that education systems evolve meet students' needs and their communities as was discussed by Roy, 2015, Anthony et. al., 2016 and Busthami et. al. (2015).

It is of paramount importance that teachers are trained on this vital tool in our quest to educate todays' children; there is an assurance of quality outcomes as was also discussed by Anthony et.al, (2016). This enhances the way they deliver content to learners. This is similar to what was found out by Nwigbo & Madhu (2016). Students need more than rote subject matter. For this reason, core academic subjects are foundation for 21st century learning. All the 21st century skills can and should be taught in the context of all academic subjects as was the findings by Busthami et. al., (2015). The teachers from schools that participated in the survey reported to be responsible for organizing training on ICT integration for teachers, assisting departments to plan lessons using ICT gadgets as well as putting in place templates for recording results. Of the 3 senior secondary schools, only one had an active team which was working on the plan to have all department taken through ICT integration training.

Furthermore, assessment should incorporate broader use of performance based measures that focus on high order thinking and measure skills such as Critical thinking, Problem-Solving, Communication Skills ICT literacy also an argument raised by Roy (2015). This is critical in the teaching and learning process and offers the teacher the role of being a facilitator, which is a by 21st Century Skill. This agrees with what was discussed by Roy (2015) and Busthami et. al. (2015). All schools visited indicated that there was no e-content developed and available for them to use. The curriculum was reported to be having some objectives that require use of technology in teaching-learning process. The teachers though, reported that they do not to pay much attention to such as the syllabus is long and also the lack of CT gadgets and internet accessibility in their schools hamper them from fully engaging in use of technology.

**Conclusion**

The role of a teacher is very much important in teaching-learning process. ICT cannot replace the teacher; it can aid the teacher in the process of teaching and make the teaching–learning process more interactive. The effective use of ICTs in teaching-learning process also depends on teacher's ICT competency and skill. So the teachers have to realize that if the students are to achieve a high level of competency and competitiveness, they have no other choice but to adopt technology as an integrated tool in the field of education.' The modern technologies including new 21 CLD has changed the total scenario of teaching learning process. ICT–enhanced learning environment facilitates active collaborative, creative, integrative and evaluative learning as an advantage over the traditional method. The teachers in schools from North East Region indicated that teaching with technology makes learning interesting but due to the bulkiness of the syllabus and the limited resources, they find it difficult to implement. As a result of the reluctance, there hasn't been much impact of the learner performance.

Several surveys are showing that ICT use in education system of developed nations is comparatively advanced than ICT used in education system of developing countries. The results obtained from the survey indicated that there is very little that the schools are doing to embrace teaching with technology. This the indicated that lack of internet accessibility, lack of resources and the heavy syllabi as factors discouraging them from trying. The few that embarked on teaching with technology, they indicated that learners are lively in class and tend to show quality results in Mathematics, Science, Design and Technology as stated by teachers in one (16.7%) junior secondary school. Those that were trained in 2016 but did not implement reported to have forgotten and will need to be refreshed. There is need to introduce ICT innovative pedagogies in to the classroom, creating network among educational institution. This will strive towards improving overall standard of education by reducing the gap between the quality of education in urban area and rural area, initiation of smart school with objectives to foster self-paced, self-assessed and self-directed through the application of ICTs, and developing ICT policy for education and training. All the schools from which data was collected have ICT integration policies but are not in operation. There is need for capacity building to equip teachers/schools on the importance of implementing the policies. It is vital to train a teacher for quality outcomes.

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**Article 7**

# Promising approaches in teacher professional development, the case of St. Mary's Ediofe girls' secondary school

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**Abstract**

This is an intra-school study that was designed to be conducted within my work station, St. Mary's Ediofe Girls' Secondary School. It was designed to investigate if locally sanctioned scholarly strategies could supplement college training the teachers go through, so that their performance might improve. The policy makers of the school, (BOG) then had to establish approaches that enhanced teacher professional development. The study then had to show that training institutions did not do enough to prepare the teachers because the teachers' preparation for teaching showed a huge variance in reference to STEM and competency teaching. I considered the quality of teacher preparation for teaching as a standard for gaging their eventual performance. The way the various teachers prepared for teaching showed a huge difference that then impacted on the way they taught. The projected benefit would then be the much-desired improvement in the quality of education and learning in the classroom, a recipe for review, renewal and extension of teachers' commitment as change agents to the moral purpose of teaching.

**Key words and abbreviations:** *Intra-School Study (ISS), Continuous professional Development (CPD), Collaboration, Contextual Teaching and Learning (CTL), Board of Governors (BOG), Teacher Education for South Saharan Africa (TESSA), Teaching references (TR)*

## Introduction

There is a growing concern that teachers do not often undergo a total formation in a training institution. The unequivocal result is under performance. Only after some good time that the teacher would be seen to enbetter his wits while on the job, especially through continuous professional development. He would then develop into a full professional teacher through every day practice, experiences and opportunities, which by design should be intensive, collaborative and evaluative, with a view to laying emphasis on quality and competence-based education.

## Review of related literature

Thomas B. Corcoran (1995) contended that to help a teacher to teach well, a review must be made of the professional development in elementary and secondary school education by improving its organization, costs, effects on practice and the principles for guiding future professional development programs.

Jennie Whitcomb et al, postulated “nurturing a growing talent”. Envisaged by president Obama, a nation can be transformed through a commitment to give the youth access to quality education by a quality teacher as a focal point in the education agenda.

**Methodology**

Based on the recommendations of the BOG, I followed up teachers in the implementation of good teaching strategies. I had the opportunity to look at the preparation documents of all the 49 teachers in the school. As I assessed the quality of their teaching reference (TR), I put them into two categories. Category 1 was for teachers whose TR were of a good quality. Category 2 was for teachers whose teaching references were questionable. I then followed them up to class to observe the implementation of their prepared lessons, category by category. The intention was to see if the preferred lesson objections were achievable in line with STEM teaching and competency- based learning.

**Design of the study**

This is an intra-school study employing scholarly approaches. Although the benefits of some of the practices may not be measurable, they have certainly impressed psychologically and positively on the teachers so much as to evoke the need to share this experience. The Board of Governors (BOG) of the school has devised two main strategies to raise and maintain the professionalism of the teachers in the school through helping them to teach well and enabling their “talents” to grow. These practices have been in action for the last eight years:

**Findings**

1. Teachers who embraced the strategies of teaching well prepared and taught their lessons well. They prepared good TRs i.e.; schemes of lessons, lesson plans with SMART objectives, and made good records of work and learners marks. They inevitably added a lot of value to show that they actually an extra mile beyond the institutional training ideals.
   These teachers hugely displayed some talents that were unique and interesting. Many would show that they were sharing with their counter parts in other schools and even within the school through some social media platforms some of which they were administrators.
   Others showed evidences that they were creating learning resources and sharing with others, writing pamphlets, improvising teaching and learning materials using locally available resources and others like the author of this paper getting involved in writing concept papers for international conferences such as COMSTEDA.
   I rated this category proficient.
2. Teachers who could not fully embrace the strategies of teaching well either made poor TRs or made none could not teach well. Besides, they be fearful and suspicious of any body who came around attempting to offer support supervision. They as a result taught lessons whose

objectives could not be achieved, for they were either not SMART or you could not see what they intended to teach. These teachers were rated average.

**Discussions**

The BOG borrowing from Thomas B, Concoran, had to make it a policy to propagate the following approaches with respect to helping teachers to teach well and enabling growth and nurturing of talents to promote the expertise of an accomplished teacher through;

a) Encouraging teacher networks and collaboration. Every year, we benchmark with some schools in the country, visit them and try to copy some of their good practices. We organize academic visits and share academic materials with our partner schools on some plat forms like WhatsApp, Instagram and telegram. We share challenges and share opinions through these media platforms and through these, a lot has been achieved.

b) Meeting the cost of professional development. Every year, the school sends out teachers for continuous professional development courses, facilitating them. One such practice is the INSETs organized by SESEMAT foe all the teachers of Science and Mathematics. Some of our teachers are being paid their tuition in the universities and colleges, encouraging many of the teachers to try hard so that they may as well benefit from this arrangement.

c) Teachers have inevitably been acculturated into carrying out research. I for one have benefitted from this endeavour. I was facilitated for a SMASE conference to Zambia in 2017 and this year-round, I am destined for Nairobi, Kenya.

d) Policy makers focusing on central issues and setting clear goals for policy implementation, and evaluation. The central issues are academic related, with the teacher as focal point. Teachers who are BOG employed are made to measure to some standards as they get their appointments. In policy discussions, reflecting on the human capital policy opens up educational opportunities for narrowing up the achievement gaps. Additionally, the policy of recruiting the best and the brightest teachers and retaining only the most effective of them constrains the resource basket to a lesser extent, so allowing for devotion of a reasonable remuneration of the teachers for their meritorious performance and commitment.

e) As envisaged by president Obama, a central call to transform a nation is the commitment to give the youth access to quality education. His education plan that has been copied by our school/ country focusses on recruitment, and rewards for the teaching force. Extra efforts by the staff are appreciated financially and morally. This has basically triggered dual motivation, both intrinsically and extrinsically.

f) Each time some teachers retire, new ones are recruited for replacement so that no personnel gaps are left unfilled.

g) Teachers nationally, have learnt to appreciate the extrinsic rewards offered by the employer(s). From earning a few thousands of shillings in the nineties, a long stride has been made that teachers now earn a fair salary this time round. The constitutional provision for formation of trade unions makes it democratic enough for the workers/teachers to negotiate their emoluments with the employer.

## Conclusion

Teaching is a complex intellectual and emotional task, a force to reckon with. Learning to teach well is a developmental process that unfolds over time when teachers enjoy an appropriate support and encouragement and are given opportunities to learn beyond the class room experience. Then the hurdle to race to the top become easy to overcome.

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TESSA Educational materials

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Jennie Whitcomb et al. Nurturing and Growing Talents.

**Article 8**

# Reinforcing evidence based research among lower-middle education level; A solution to STEM educational reforms

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**Abstract**

Despite a wide call on reforming the STEM curriculum across African countries to have relevant education system capable to produce the 21st century learners to drive their economies; the execution thereof remains somewhat at snail pace. Why does such plea for reforms return again and again? This paper identifies there is a low implementation of STEM education at lower-middle education. As such nurturing of children's creativity and innovativeness is delayed until at higher education. Some findings have argued that insufficient research based investigations compromise the standards of early education. In this positional paper we seek to show how reinforcing evidence based research among lower-middle education STEM teachers' remains the solution to repeated "sought after" STEM educational reforms. In doing so, we place evidence based research at the center of contemporary reform efforts and the effect of this process on the growth of teacher knowledge and subsequently on student learning. The race to transform economies lies heavily in investing in research and development in education. The information will be gathered through literature review-content analysis and interview. The findings aim to inform the policy makers, curriculum developers about the importance of evidence based research in lower middle education.

**Keywords:** *STEM, Evidence Based Research, Lower-middle education level, STEM education reform, teacher training*

## Introduction

STEM education has undergone a series of call for reforms with a hope to being a solution to many African countries education system that has been under criticism for lacks in terms of employment creation, economic diversification in directing technological innovation revolution. With an exception of few that have reached the break-even point, more still needs to be done in order for such reforms to bear fruits. This paper notes that there is a significantly low implementation of research skills at lower-middle education. It is also evident that the teacher training institution are less likely to emphasize evidence based research as a learning methodology. With teacher trainees taking evidence based research as a subsidiary training, the lower-middle education level is suffocated of research exposure at tender ages. Hence this paper calls for intensification of evidence research especially at lower- middle classes. This paper opinionated that empowering lower-middle level with evidence based research coupled with outcome based education rather than giving students exams for the sake of passing to the next level is the cure to the reforms. First if the teachers are exposed to evidence based research during training then the classroom pedagogy reinforce applying the same approach during teachings; it endows creativity and innovation in both teachers and learners. Teachers via available structures can employ informed decisions in transforming the education system, recommending cognizant ideas that informs policy change. As such educational reforms are not left to political will but to evidence, and teaching doesn't only remain an activity to pass exam but a process to produce tangible, empirically testable and replicable results that drive economies. The overriding assertion of this paper is that research-based teacher education and professional development are key dynamics in fruitful implementation of STEM education reforms especially at lower-middle level of basic education. In its study, this paper will underscore on the following captions; the dynamics of STEM education reforms, the importance of teacher content knowledge as well as repairing the research-practice link in stimulating STEM education reforms. The information will be gathered through literature review-content analysis and interview. The study intends to inform the policy makers, curriculum developers as well as teacher trainers about the importance of coupling evidence based research in teacher training and teaching instruction to transform education system.

**The dynamics of stem education reforms**

Despite a wide call on reforming the education system across African countries to implement the STEM curriculum in order to have relevant education system that will drive the 21st century economies; the implementation remains somewhat at snail pace. Why do reforms re-emerge over and over? This paper submits that mending the relation concerning evidence-based education research vis-a-vis teacher education training can address the challenge of sluggish STEM education reform implementation. That is, this paper prioritizes placing evidence research-based STEM teacher tutelage in the center of present-day reform efforts as well as appreciating the spill-over effect such has on the development of teacher knowledge and subsequently on student learning. The key hint is that research-based teacher education and professional development are strategic dynamics in positive execution of STEM education transformations. Nonetheless, further enquiry is desirable to examine this assertion. The above-mentioned approach zero in the teacher-candidates' active exposure to research-based pedagogies as learners and as upcoming teachers. STEM education restructuring entails the use of methodical research practices that can yield valid, reproducible, empirically testable, and generalizable conclusions.

Hirsch (2002) claims educational policies and trends are often centered on questionable politically motivated inquiries that seeks to find generalizable results, and yet under a closer scrutiny falls short of adherence to the rigorous standards of falsifiability, integrity, and scientific scepticism.[1]The lack of the empirical investigations reporting negative, "politically incorrect" or "inconvenient" effects (AERA, 2006) compromises the standards of educational evidence based

[1]Hirsch, E. D. (2002). *Classroom Research and Cargo Cults*. Policy Review: Hoover Institution October-November.

research, echoing what Richard Feynman (1974) nicknamed the Cargo Cult Science syndrome- "*We really ought to look into theories that don't work, and science that isn't science.*" Could this mean we misinterpret STEM education from being an evolving research arena, involving educators set on the contrary ends of the research spectrum: from the positivist research (examining an objective reality) to the purely interpretivist and descriptive research associated with the humanities and social sciences (interpreting a subjective reality)? If so then, the above words of Richard Feynman (1974) are long overdue if we want to see STEM education stimulating sustainable employment creation, technological advancement as well as driving self-sufficient economies. Evidence based research can be transformational both to teachers and to students- measured by contributions individuals bring to their community.

Previous researchers have made great strides in understanding how students learn STEM subjects and how they can be supported. Relative progress has been noted post-secondary level where increasing demand of tertiary institutions focuses on revising their syllabi, aligning teacher promotion and development policies to incentivize and reward implementation of evidence based instructional practices for all academic ranks. This paper highly regards that implementation of such policies is long belated at primary school and secondary schools to promote evidence based research that can inform quality resolutions. There is also an increasing significant evidence-based studies evaluating the effectiveness of different academic approaches at a post-secondary level since they are "the near industry" cohort that matches curriculum and actual market requirements. In contrast, much more research is required for the lower levels (primary-senior) on how to support teachers in integrating academic evidence-based pedagogies to what is to be considered as evidence that can be used as a base for informed policies towards STEM education. It is time to realize that in order to change how students engage with STEM we have to shift the way we educate lower level teachers and how we support them during their teaching careers.[2]Since a substantial number of teachers who teach STEM at primary schools are not specialist or first major graduates in these fields and the majority of elementary teachers have rather limited mathematics and science knowledge, therefore we have to devise a strategic alternative that engages all teachers in STEM education across all levels. The causes of limited performance in these disciplines cuts deep and they varyingly implicate the inner mechanisms of our education system. It will not make sense to isolate the STEM subjects from the system itself, nor will it be a sustainable solution to build a robust post-secondary school STEM program on a pathetic elementary school curriculum. Doing so is planning to fail because fixing the challenges in the STEM subjects without fixing the larger system, you will result in any reforms being limited by the system. This is not for the reason that educators are opposing the whole idea or fail to share hopes but it is because they are as much trapped by the system.

[2]Schmidt, W. H., Blömeke, S., Tatto, M. T., Hsieh, F.-J., Cogan, L. S., Houang, R. T., et al. (2011). *Teacher Education Matters: A Study of Middle School Mathematics Teacher Preparation in Six Countries.* New York, NY: Teachers College Press.

The argument of this paper is that in order to break the vicious circle of STEM education reform failures; we need to examine and enforce evidence based research among lower-middle level to repair the broken link between the evidence-based education research and teacher education practice. This will enable the education system to groom the 21st Century STEM teachers who are open and willing to collaborate with their STEM colleagues, to promote inquiry in their teaching while inspiring integrated STEM education in their classrooms.

**Teacher content knowledge**

The desire for many countries to have industrialized economies seeks to shift focus on the development of teacher knowledge and skills, as well as teachers' beliefs and attitudes about learning. Some commentators believe that for the teacher to effectively express and share knowledge with students, there is need to critically assess knowledge acquisition methods from training-continued learning vis-à-vis effective content delivery in classroom; that is, teachers' knowledge comparative to pedagogical content knowledge. Shulman (1986) defined teaching as a profession that requires a highly specialized knowledge[3] with an ability to purposefully use technology to stimulate student collaboration, active engagement and tangible learning beyond what was possible earlier. [4] Marina Milner-Bolotin (2018) emphasized that it is not only important that teachers learn how to use educational technology for teaching a specific subject, but to learn how to incorporate it to promote a different kind of student collaborative engagement with the subject's content-especially important for teaching STEM as a unified concept. [5] MacArthur (et al 2011) underscores that while these tools are freely available; in the absence of teachers' knowledge and enthusiasm about how to use these tools deliberately to promote student learning, these technologies will remain under-used if not misused tools. It is necessary to explore teachers' value of attitude about learning and the growth of their own knowledge for teaching, as well as their ability and willingness to incorporate innovative research-based pedagogies. Teaching like any other profession can be challenging especially in this era where teaching requires incorporation of technology, where an educator needs not only to learn how this technology functions, but also how to use it to benefit students.

This paper concurs with Hempenstall (2006) that education has a history of regularly adopting new ideas, but it has done so without the wide-scale assessment and scientific research that is necessary to distinguish effective from ineffective reforms.[6] At the core of the education system reforms is the understanding that content knowledge is a complex dynamic construct whose growth is affected by the teachers' initial learning experiences, attitudes about learning, views about teaching as a profession, their practice, and opportunities for professional development, reflection, and peer

[3]Shulman, L. S. (1986) Those who understand: knowledge growth in teaching. *Edu. Res.* 15, p 4–14.
[4]Milner-Bolotin, M. (2004). Tips for using a peer response system in the large introductory physics classroom. *Phys. Teacher* 42, p 253–254
[5]Milner-Bolotin. (2018) Evidence-Based Research in STEM Teacher Education: From Theory to Practice. *Frontiers in Education* **3**.p 4
[6]Hempenstall, K. (2006). What does evidence-based practice in education mean? Australian Journal of Learning Disabilities, 11(2), p83-92

collaboration.[7] As such, it is imperative to examine available research evidence on the growth of teacher knowledge during teacher education and consider how it might inform STEM teacher educators. Teachers' conceptualization of the subject content and purpose dictates formative interactions as well as school practice. Outcome based education system encourages student engagement for effective learning. Encouraging students does not only limit to question and answers led by the teacher but a measurable interaction where students are allowed to dissect concepts, understand them and be able to practically draw deductive replicable projects of course with the moderation of the lead instructor. The same can be extended to student's assessment procedures aligned and encourages outcome based education system.

**Repairing the research-practice link**

Teaching has suffered in search of community respect; due to its limited efforts to embrace the outcomes of empirical research as the major determinant of its social capital practice; as well as a prevailing science-aversive culture prevalent among education policymakers and teacher education faculties. According to Davies (1999), the goal of evidence-based education research is to pose answerable questions about education, to answer them using professional and scientific research standards, and to share these findings with the wider community.[8] As Cuban (1990) pointed out almost four decades ago, in order to solve this recurring problem we have to ask the right questions:

*The re-surfacing of school transformation imply that the reform has failed to eliminate the problems they were intended to crack. Analysts ask: Are we attacking the right problem? Have the policies we adopted fit the problem? Have practitioners implemented the policies as intended? (p. 5–6)*[9]

This paper argues that evidence based research means making a decision, challenging the status quo, and proposing new innovations based on comprehensive research information not on opinion. Davies suggests that evidence based education research can be carried out at two stages; firstly, the researchers employ readily available evidence to analyze questions and concerns in order to bring solutions. Secondly they plan, carry out, and disseminate original research to generate new evidence that answers research questions, suggest and test competitive analysis, interpretation of data, propose testable competing theories challenge widely accepted assumptions. [10] At both levels, the information gathered should warrant the conclusions and implications of the research as well as being sufficient to recommend and refute alternative interpretations. Evidence-based education research aims at advancing our knowledge of educational issues to inform both policy and practice; it inspires informed scientific revolution. Kuhn (1996) writes that it is especially

[7]Milner-Bolotin. (2018) Evidence-Based Research in STEM Teacher Education: From Theory to Practice. *Frontiers in Education* **3,** p 4

[8]Davies, P. (1999). What is evidence-based education? *Br. J. Edu. Stud.* 47, (2) p 108–121

[9] Cuban, L. (1990). Reforming again, again, and again. *Education Research Article.* Vol 19, Issue 1, p 3–13.

[10]Davies, P. (1999). What is evidence-based education? *Br. J. Edu. Stud.* 47, (2) p112

suitable for examining STEM learning, as STEM fields are the birthplace of scientific landmark.[11]This paper observes that evidence-based education is not a panacea, but is a set of principles and practices for enhancing educational policy and practice.

This section highlights repairing the link between evidence-based STEM education research and teacher education practice can be beneficial. We consider how education research can support the development of STEM teacher-candidates' knowledge for teaching, their growth mind-set, and positive attitudes about the role of research in their classroom instruction.

Student conceptualization of mathematics, chemistry, biology, engineering and physics subjects has been followed by many researchers, however, what remains is the incorporation of such findings into the STEM teacher education to align it with pedagogical knowledge for teachers. Researchers have found that the rapid adoption of the STEM idea calls for new understandings about how to restructure the curriculum, how do teachers improve knowledge/expertise to implement the interdisciplinary curriculum, and how do students most effectively learn in an amalgamated and multidisciplinary learning environment.[12] Milner-Bolotin (2014) revealed that in Canada STEM teacher-candidates first earn a relevant B.Sc. degree and then depending on the province complete a 1- or 2-year long teacher education program. In Botswana STEM teachers aspirants at College of Education enrol for 3 years specialized program (for Secondary teachers) while for primary teacher trainees concurrent teaching is common.[13] Even though in Botswana, a significant number voluntarily spend extra 2 years at university level to upgrade to degree level, majority remains in class with diploma qualifications. Due to their limited duration, teacher education programs usually have little time to devote to the development of teacher-candidates' content knowledge and consequently their pedagogical content knowledge. Therefore, these programs are left to chance but to assume, that teacher-candidates have already mastered the necessary content and only need to develop their pedagogical delivery. Therefore, not devoting enough time to helping teacher-candidates revisit their content mastering and connect it to the relevant classroom instruction becomes problematic.

The same applies to general pedagogical courses aimed at promoting active learning, formative assessment, inquiry, or technology-enhanced pedagogies. Crouch and Mazur (2001) discovered that there is ample research evidence that active engagement is important for STEM learning.[14]As such, Milner-Bolotin (2018) revealed that in order to implement technology-enhance pedagogies in STEM classrooms, teachers have to acquire very specific skills, such as an ability to design and facilitate inquiry-driven activities, to use STEM-specific educational technologies, to implement

[11]Kuhn, T. (1996). *The Structure of Scientific Revolutions.* Chicago, IL: University of Chicago Press
[12] Journal of Research in STEM Education (J-STEM),Volume4, No. 2 at http://j-stem.net/ accessed on June 2019
[13] D. Roy, Assistant Dean- Senior Lecturer at Molepolole College of Education, telephonic interview conducted on 21 June 2019.
[14]Crouch, C. H., and Mazur, E. (2001). Peer instruction: ten years of experience and results. *American Journal of Physics.Vol* 69, Issue 9, p 970–977

inquiry-based labs and projects.[15] In order to do that, teachers have to understand how and why these activities facilitate learning (the research evidence), and experience these learning environments first as learners and then to reflect on these experiences later as teachers. Repairing the research-practice link in this context means that STEM teacher education should be informed by STEM education research. Only after teacher-candidates have multiple opportunities to challenge their own STEM understanding and reflect on how one learns STEM, they will be open and capable to enact research-based pedagogies in their own classrooms. In this advocacy we emphasize the importance of deliberate pedagogical thinking with technology as opposed to using technology for its own sake. Teacher candidates will not only expand their pedagogical content knowledge, but also learn how to use technology purposefully to promote student learning. This therefore calls teacher educators to continuously collect and analyse evidence on the pedagogical effectiveness of their own courses, the development of teacher-candidates' pedagogical content knowledge, teacher-candidates' attitudes about learning and the role of research in teaching.

This paper suggests a pedagogical approach for incorporating research-based pedagogies into teacher education practice and illustrate how it can be applied in the context of STEM teacher education. This approach follows four stages as suggested by Milner-Bolotin (2018) being (a) **Model**: Teacher-candidates experience research-based pedagogy; (b) **Reflect:** They reflect on their experiences as learners and as future teachers; (c) **Research**: They discuss the research foundation of this pedagogy; (d) **Practice**: They practice incorporating this pedagogy in their own teaching. This approach employ and expose teacher-candidates with innovative trainings as students and as future educators and acquire positive attitudes about the significance of evidence-based education research in their own practice.

Teachers make a difference in the achievement of students, Schmidt (et al 2011) concludes that teachers play an important role in selecting topics for classroom instruction, organizing and providing classroom learning opportunities;[16] the question is how teachers are trained to acquire knowledge of the curriculum which they will be subsequently be required to teach. Schmidt (et al 2011) alludes that preparing highly competent teachers is a matter of public policy and cross sectional concern in every society.[17] Mr. Brett Wallington warned that teachers should teach maths and science with a purpose to empower students for solving future problems rather than just to make them pass examinations.[18] It has come to realization after a series of trials that traditional teacher-centered pedagogies are largely ineffective for promoting conceptual understanding

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[15] Milner-Bolotin, M. (2018). *"*Evidence Based Research in STEM Teacher Education from: from Theory to Practice". Curriculum, Instruction and Pedagogy Article, 92 November), p 313-316

[16] Schmidt, W. H., Blömeke, S., Tatto, M. T., Hsieh, F.-J., Cogan, L. S., Houang, R. T., Bankov, K., Santillan, M., Cedillo, T., Han, S.I., Carnoy, M., Paine, L., and Schwille, J. (2011). *Teacher Education Matters: A Study of Middle School Mathematics Teacher Preparation in Six Countries.* New York, NY: Teachers College Press, p 1

[17] Schmidt, W. H., Blömeke, S., Tatto, M. T., Hsieh, F.-J., Cogan, L. S., Houang, R. T., Bankov, K., Santillan, M., Cedillo, T., Han, S.I., Carnoy, M., Paine, L., and Schwille, J. (2011). *Teacher Education Matters: A Study of Middle School Mathematics Teacher Preparation in Six Countries.* New York, NY: Teachers College Press, p 1

[18] Brett Wallington, Standard Chartered Bank Community Social Mobilization officer, Johannesburg South Africa during the 2019 Nedbank Tour De Tuli Charity ride networking discussion in July 27,2019

(Hake, 1998) and stimulating positive attitudes about innovative science.[19] Henceforth, attention has been focused on engaging in STEM subjects research as essential driver for economy transformation. The availability of new educational technologies augments teachers' active engagement in research learning during their teacher training that this paper calls for. This will allow teacher trainees opportunities to practice designing and modifying pre-existing subject-specific educational materials, such as conceptual STEM questions for content pedagogy ownership.

**Discussion**

Various literatures portray how South Korea implored integrated STEM as an approach to quality STEM labour force in preparations for a highly industrialized technology led society. On the other side the United Kingdom had set up an educational policy outline towards stimulating STEM integration both in and out of schools.[20] Likewise, in 2012 Germany instituted a STEM forum to sponsor formal and informal STEM education for all levels of education.[21]These concerted efforts in technologically established countries to re-engineer STEM education are geared towards addressing challenges which African states find themselves at loggerheads with in modern days; which require strengthening the literate workforce to address global issues. In emulating technological hulks, African governments ought to designate a considerable financial muscle to sponsor STEM education. Such sponsorship can be outlined in various means to stimulate innovative thinkers from a younger age by integrating ideas from STEM fields in all subjects. Evidence based research and practices informs implementation of new ideas, talents or products fashioned by multidisciplinary thinking. In this approach, students have exposure to real world simulation problem solving by investigating probable resolutions through application of skills and knowledge from other disciplines. Exposing students to problem solving learning technique, it sharpens their cognitive, analytical skills and creative thinking. During the process, students brainstorm as well as relay multiple answers compared to a structured single answer scenario. Students can analyse the effectiveness of their strategies with an option to correct or re-apply another alternative. STEM education should improve student's use of technology during pre-college education to cultivate their understanding of how things work as well as to engage in problem solving of real life simulations. Whereas there have been great initiatives for integrated STEM disciplines and instructional approaches across the continent, such efforts are curtailed by lack of research and ineffective implementation.

Kang (2019) denotes that upon reforming the education system through the governmental STEAM initiative in 2011, South Korea was wise to skew its reforms towards professional development of

[19]Hake, Richard R. (1998). Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics' test data for introductory physics courses. American Journal of Physics, 66(1), p 64-.69
[20] STEM Learning (2018). About us. https://www.stem.org.uk/ Accessed 5 May 2020
[21] Nationales MINT (STEM) Forum. (2014). MINT-Bildung im Kontext ganzheitlicher Bildung [STEM-education in the context of holistic education]. Munich: Herbert Utz Verlag.

STEAM to both elementary and secondary school educators.[22] This is said to have been executed through a proper teacher Professional Development courses and STEAM Research Group of Teachers Support package. According to Kang, the professional development conducted formal courses to educators of all levels and subjects without any financial charge as follows; an online course as an introductory level, a basic blended program, and an advanced combined program. The preliminary online course delivered an outline of STEAM for teachers to understand the policy schedule, its fundamental aims, positioning toward approaches to teaching integrated STEAM lessons, examples of STEAM lessons and illustrations which segregate courses for teachers at different school levels. The basic blended program was designed to familiarize teachers with cutting-edge science and technology by witnessing science and engineering labs and to expose them to similar STEAM programs developed for schools. According to Kang (2019) the program covered proficiency for teaching STEAM in the classroom including subject matter knowledge, pedagogical content knowledge for integrated content, teaching strategies, and teachers' own STEAM literacy development. At the end of the semester, teachers were awarded an occasion to share the results of their STEAM lesson execution with other participants. [23] Teachers who have finished the basic program or any STEM teacher progressed to advanced professional development program with a goal to develop competency in creating STEAM contents for teaching[24]

The STEAM-research group of teachers support program existed to support teachers' self-guided professional development by facilitating teacher groups' work as learning communities responsible for creating STEAM lesson plans, implementing them, and reporting their effects on student learning.[25] By 2012, STEAM teaching and learning materials development projects were funded to provide teachers with evidence-based effective STEAM curricular materials. Each funded project was anticipated to develop curricular materials for elementary or secondary schools; its materials were then tested in schools their effects measured and reported. [26] As of June 2019, a total of 666 program modules developed and tested are available at the STEAM homepage hosted by Korean Foundation for the Advancement and Creativity.[27] However, a further research can be conducted to investigate the teacher's implementations vs their perceptions of STEM education in determining the effects on STEM reforms, as well as the level of student's engagement on the subject matter. This will segregate the teacher's personal perceptions vis-à-vis

[22] Kang N. (2019) A review of the effect of Integrated STEM or STEAM (Science, Technology, Engineering, Arts, and Mathematics) Education in South Korea, Asia Pac, Sci, Educ, 5,6, p6

[23] Kang N. (2019) A review of the effect of Integrated STEM or STEAM (Science, Technology, Engineering, Arts, and Mathematics) Education in South Korea, Asia Pac, Sci, Educ, 5,6, p6-7

[24]Korea Foundation for the Advancement and Creativity (2019). About STEAM. Retrieved from https://steam.kofac.re.kr/?page_id=11269 accessed May 12, 2020

[25] Jho, H., Hong, O., & Song, J. (2016). An analysis of STEM/STEAM teacher education in Korea with a case study of two schools from a community of practice perspective. Eurasia Journal of Mathematics, Science and Technology Education, 12(7), 1843–1862. https://doi.org/10.12973/eurasia.2016.1538a.

[26] Kang N. (2019) A review of the effect of Integrated STEM or STEAM (Science, Technology, Engineering, Arts, and Mathematics) Education in South Korea, Asia Pac, Sci, Educ, 5,6,p7-8

[27] Korea Foundation for the Advancement and Creativity (2019). About STEAM. Retrieved from https://steam.kofac.re.kr/?page_id=11269 accessed May 13,2020

triggering student's intrinsic motivation towards STEM. There is a lack of research on the effect of the interdisciplinary nature of STEM. The interdisciplinary aspect of STEM should be further studied as a unique feature and goal in order to inform ways of designing meaningful interdisciplinary activities for STEM.

**Conclusion**

This study examined the implementation of evidence based research as a solution to STEM education reforms and reviewed the studies about its effects on teaching and learning. Based on a literature review, evidence of the effects, challenges, and further research topics were identified. Studies have shown that integration of STEM research in lower education remains the cornerstone to the education reforms. Studies have argued that proper professional development remains a critical reform factor that increases STEM educators' recognition of the initiative and confidence in teaching STEM. A further research on the connections between teachers' perceptions and implementation of STEM research their classroom practices is necessary. STEM will continue to be a burden to science teaching, when STEM is considered less multidisciplinary learning, and more of a new way of teaching science. Given the current discipline-based curriculum, STEM should be carefully conceptualized, and strategies for teacher collaborations across different subjects should be carefully planned and executed for the efficient results. However, the interdisciplinary aspect of STEM should be further studied as a unique feature and goal in order to inform ways of designing meaningful interdisciplinary activities for STEM. Various economies grapple with implementing the STEM curriculum in order to have relevant education system that will drive the 21$^{st}$ century economic revolution; the impact remains somewhat at snail pace despite immerse concerted reforms. Why do reforms return again and again? There is a famous phrase by Sir Winston Churchill saying "those who fail to learn from history are doomed to repeat it."[28] Churchill's famous saying about human failure to learn from the past is still relevant today. However, we often forget that it applies not only to the history of civilizations, but also to the history of educational reforms and their almost inevitable failure. In the era where humanity is overwhelmingly fashioned by technology, many countries have been in a race to significantly tackle challenges restraining economic development as well as employment generation for their citizens by engaging in a shift towards tangible STEM learning. [29]This has placed more burden not only to remedy the scant student performance recorded on the conventional assessments of mathematics and science subjects; but also to lure them away from the growing STEM disengagement by incorporating technology in problem solving. In order to address the problem of limited research among teachers, educators and policy makers ought to repair the broken link between the evidence-based STEM education research practice vis-à-vis educational policy informing the former. This paper concludes that intensifying evidence based research on STEM

[28] Winston Churchill in a 1948 Speech to the House of Commons, available at http://www.nffonline.com/industry-news/2014/08/28/those-who-fail-learn-history-are-doomed-repeat-it accessed on August 6,2019

[29]OECD (2016). *PISA 2015 Results in Focus.* Paris: OECD Publishing.

education at its infancy levels remains the ultimate solution to frequent educational reforms. We recommend for support on researchers in conducting evidence-based STEM education that produces reliable and generalizable results that will inform educational policy and empower future practitioners. We call on STEM education researchers and teacher educators to incorporate evidence-based research into teacher education practice, to measure the effectiveness of their pedagogical innovations, as well as to share these results with the larger community.

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**Article 9**

# Need for in service training towards strengthening innovative pedagogies, inclusive and quality education

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**Abstract**

Teacher resource is one of the major and critical determinants of the quality of teaching and learning in an educational institution towards realization of desired learning outcomes especially in STEM. Therefore, there is need to promote the promising approaches for effective teaching and learning. One such approach is strengthening inclusive and innovative pedagogies. The purpose of this paper was to highlight with a view to promote and adopt the inclusive and innovative pedagogies. Responses were obtained from 28 selected teachers and results analysed by descriptive statistics. The finding was: there was need for enhancing 21st century skills/competencies, innovative and inclusive pedagogies. Recommendations were that: Ministry of Education and Teachers Service Commission due to her expanded mandate on teacher development and vision of transforming teaching to heights of professionalism should focus and enhance in-service trainings on these pedagogical approaches. The SMASE model ought to be explored and strengthened and adopted.

**Key terms:** The 21$^{st}$ century skills/competences, innovative and inclusive pedagogies

**List of abbreviation and acronyms:** CEMASTEA - Centre for mathematics, Science and Technology Education in Africa; ICT- Information and Communications Technology; KICD- Kenya Institute of Curriculum Development; MoE - Ministry of Education; PC- performance Contract, SMASE- Science and mathematics subjects Education; SMASSE- Science and mathematics subjects for Secondary Education; TPAD- Teacher performance and appraisal Development; TSC - Teachers Service Commission; UNICEF- United Nations Children's Fund

## Introduction

### Background of the Paper

The 21$^{st}$ century learner is globally aware, a communicator, a self-directed learner, an innovator, financially and economically literate, information and media literate, a collaborator, a problem solver, civically engaged and critical thinker (Jwan, 2016). Collaborative pedagogies have the advantage of developing learners with 21$^{st}$ century skills such as creativity, critical thinking, problem solving and innovation (Njui, 2017).

Experiential learning requires the student to not only engage in the experience activity, but also requires them to reflect upon their learning and how their skills learned through their academic studies can be applied beyond the classroom. It encourages collaboration and exchange of ideas and perspectives. Also builds on past knowledge and experiences (https://carleton.ca/experientialeducation/what-is-experiential-education/). Experiential learning is a process through which students develop knowledge, skills, and values from direct experiences outside a traditional academic setting. Well-planned, supervised, and assessed experiential learning programs can stimulate academic inquiry by promoting interdisciplinary learning, civic engagement, career development, cultural awareness, leadership, and other professional skills (Experiential Learning Center, n.d.).

Teachers are responsible for creating effective learning environments. They achieve this by building consistent, comprehensive and improved pedagogical approaches that enhance flexible and innovative learning. This requires them to be responsive to the values, needs and interests of individual learners to strengthen learning communities and employ pedagogical approaches that support different ways of thinking and learning in order to enhance inclusion of all learners. This is crucial because inclusion is among the essential components of an effective learning environment (child friendly schools, UNICEF, 2012). Ineffective learning environment promote silent exclusion of learners (Ayiro, 2019). The ultimate aim is to guarantee basic education for every learner according to their abilities and needs (KICD, 2017).

The role of skills for innovation in national curricula appears to have become more prominent in recent years. Teacher education program should orient teaching to 21$^{st}$ century principles of teaching and learning in order to develop teacher trainees with creativity and innovation skills (CEMASTEA, 2019). The curriculum should promote innovation, problem solving skills and self-reliance for achieving an individual's and national development (KICD, 2016). The 21$^{st}$ century learner has natural instinct to learn and create, therefore, the Kenyan teacher should embrace the 21$^{st}$ century learning practices that can unleash this potential (Mwinzi, 2018). Hence there is need to ascertain the role of principles and practices of effective teaching and learning in the 21$^{st}$ century. This is in a view of strengthening inclusive and innovative pedagogies to enhance learning outcomes especially in STEM.

**Statement of the Problem**

Teachers are crucial in providing quality education for all children. All children have a right to basic education regardless of their differences and diversities (Basic Education Act, 2013). This therefore calls for inclusive pedagogy, thus teachers need to understand and use the inclusive pedagogies. The teachers should build consistent, comprehensive and improve pedagogical approaches that enhance inclusive and innovative learning.

The current teaching practices in Kenya focuses on producing "A-Grade" learners and those societal settings that attach a lot of value to the test score (Mwinzi, 2018). This could be an indication that formal education in Kenya caters for a few learners with intellectual inclinations.

Learners have varied abilities, needs, backgrounds, perspectives and interests. In short experiences some of which could be emotional and hence attitude shaping and so action driving. In addition, basic education is mandatory for every child. It is critical that teacher competence in 21$^{st}$ century skills comprise of inclusive and innovative pedagogies and ability to develop and use them be ascertained. Furthermore, the Teachers Service Commission PC/TPAD identifies teachers' performance competence gaps that can be summarized as: 21$^{st}$ century teaching-learning skills and competence gaps. The tool goes ahead to highlight in-service strategy to bridge the performance gap and enhance teacher and management competences. It is therefore imperative to establish teachers and managers' response to these strategies and also establish strategies or measures to enhance teachers and management competences and skills.

**Delimitations of the Study**

The paper was delimited to public secondary schools Konoin Sub County in Bomet County. Also, the paper focused on instructional approaches and 21st Century skills/competences.

**Research Methodology**

**Research Design of the Paper**

The study adopted mixed research design. A mixed method involves the collection and "mixing" or integration of both quantitative and qualitative data in a study. In the exploratory sequential approach, the researcher first begins with a qualitative research phase and explores the views of participants. The data are then analysed, and the information used to build into a second, quantitative phase (Creswell, 2014). The aim was to establish the need for teacher and manager continuous in-service training toward acquiring, developing and perfecting 21$^{st}$ century skills and competences as well as innovative and inclusive pedagogies. To validate the observers' deductions an exploratory research exercise was undertaken to establish the needs and their extents for in-service training as well as remedial actions.

**Population of the Paper**

The population of the paper study were the teachers. There were 272 TSC employed teachers in 53 public secondary schools in Konoin Sub-County in Bomet County.

**Sample Size and Sampling Procedure**

Number of teachers involved was 28, hence were 10% sampled. The schools selected were typical: Extra-County/National, County, Sub-County Schools Categories. Snowball sampling to obtain student responses to test items from teachers/managers was done. Teachers were requested to identify and post on their What-Sapp walls student responses of interest. The selected teachers responded to the on questionnaires the extent of their level of need for the 21$^{st}$ Century skills, the TSC lesson observation guide and level of need for the teachers support and professional.

**Results and Discussions**

The study yielded the following results.

**Student responses to test items**

Teachers were requested to identify and post on their walls student responses of interest. The students' responses when considered critically have the following features:

i. Shows or depicts some expected learning outcome or behaviour
ii. Response or action demonstrated by student is not correct according to the item in question.
iii. With some coaching, guidance, clarification, correction or revision the student is likely to make the correct responses.

The implication was that in service training of teacher can enhance their ability and competence to assist students more since these responses are not random in view of the concept being tested but are intimate. The responses indicate the existence of students' ideas and experiences. If appropriate instructional methods applied for example the experiential learning could enhance exposure and increase in understanding of diverse perspectives. And this would lead to improved correct responses. It can be inferred that experiential learning approach improves the quality of teaching and learning outcomes specifically in STEM subjects. Also, teachers need to adapt and use inclusive and innovative pedagogies to enhance learning outcomes for every learner. Also, implied that skills upgrading was necessary especially on the use of inclusive and innovative pedagogies such as experiential learning that caters for diversity of classroom situations.

**Teachers' Level of need for the 21$^{st}$ Century Skills**

Teachers were asked to indicate the extent of their level of need for the 21$^{st}$ Century skills. The level of need for the 21$^{st}$ Century Skills/Competences were: ICT integration in T/learning, Interpersonal skills/collaboration/ group work, Innovation and creativity skills, Problem solving skills, Lesson study skills, Research skills, Interpersonal skills/self-directory skills, Guidance and counselling skills, Communication, Environmental management, Health safety management skills, Global awareness skills, Education legal and policy frameworks and responsibility, Financial literacy skills, Leadership skills, Accountability skills and Strategic planning, Identifying /developing learner talent and management skills (100%). Providing for learners with minor challenges/disabilities in ordinary classes (87.7%), Competence/ knowledge on professional documentation (42.9%), Teaching students with exceptional talent, music, athletics, football (96%), Planning skills (92.8%), Time management (89.3%), Project management/agriculture, computer etc. (89.3%), Examination management (82.1%), Networking skills and Civic literacy skills (71.4%). Cross cultural awareness skills (85.7%), Entrepreneur skills (96.4%), Site planning skills (60.7%), Resource mobilization and management skills (92.8%). It can be inferred that in-service training was recommended to enhance the teachers' level of the 21$^{st}$ Century Skills.

The level of need for the competencies were high except for the competence/ knowledge on professional documentation having 42.9 percent. This was an indicator that the lower need level for the competence/knowledge on professional documentation, the paperwork has been emphasised making them to somehow master the competence. And the question was: are teachers able to prepare, maintained and use required professional documents? Hence, there was need for enhancing 21st century skills/ competence, innovative and inclusive pedagogies.

**Teachers' Service Commission Lesson Observation**

The lesson observation Form or Guide has five observation areas. A score of 1, 2 & 3 means the teachers has challenges in the observation area and there was need to improve to 4&5 score. 17.8% (5/28) need to be capacity building which can be extrapolated to 53571.14 teachers countrywide. This is not a small number (Approx. teacher population of 300.000). Summary of results of teachers' self-assessment of their lowest performances on each observation area using the TSC lesson observation rating scale were: Introduction and lesson planning (80%), Content delivery (78.6%), Teaching method/technique (87.5%), Learner involvement and communication (100%) and Classroom management (86.6%). During lesson delivery, mastery of content was worth positively mentioning but other areas need improvement. Teachers were confident of content knowledge but hardly conclude lessons or do all planned activities. There existed performance gaps and this showed that intervention measures were required. The instruction supervision by use of the TPAD tool has not given teachers opportunity to improve on their performance competencies. Therefore, remedial measure is the in-service training.

The teachers were requested to provide reasons for the lowest scores. Summary of explanation of score by teachers were: Learner inability to communicate, large class size, inadequate learner prerequisite skills/knowledge, inadequate background information about learners, diversity in learners' ability, low- learner ability, lack of resources inadequate time (majority fail to conclude a lesson/do all planned activities within an allocated time), challenge of harmonizing of lesson activities/content /ideas and shy learners.

**Level of Need for the Teacher Support and Professional Development**

To obtain level of need for the teachers support and professional development the leaders were asked to score the level of need for the programs /strategies results are: Mentorship program (92.8 %), Induction program (35.7%), Coaching program (89.3%), Peer support (100%), Team teaching (96.4%), Subject symposia (85.7%), Role modelling program(92.8%), School based professional development (courses, workshop seminars) and professional support by field officer and other educationist CSO, TSC,MOE & subject specialists (100%). They were not sure how/when it was to be done or used on Intern-ship.

Percentage of teachers and education managers who desired the in-service programs were high but least of 35.7% for induction. The rest, they needed by over 80% of teachers some such as peer support and school based professional courses by 100% of the teachers. Therefore, teachers actually need all the programs except the induction program which was lowest rated. Hence, if the strategies and programs are put in place will lead to improved learning and teaching processes. It can be deduced that school based professional development (courses, workshop seminars) and peer support program are the most needed, need to be effected for effective teacher support and professional development.

## Conclusion

It is evident that the serving teachers and school managers have performance gaps in terms of 21st century skills and competences, inclusive and innovative pedagogies. Serving teachers and managers can enhance their 21st century skills and competence by undergoing experiential learning laced in-service training. The 21st century skills and competencies need to be adopted for effective learning and teaching. Therefore, there is need to enhance their acquisition. Their application and use will strengthen inclusive and innovative pedagogies hence attainment of inclusive quality education.

## Recommendations Basing on Paper findings

Ministry of Education and Teachers Service Commission due to her expanded mandate on teacher development and vision of transforming teaching to heights of professionalism should focus and enhance in-service trainings on these pedagogical approaches. The SMASE model ought to be explored and strengthened and adopted.

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**Article 10**

# The Rhodes University mathematics education project in-service BEd and collegial cluster teacher professional development model

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**Abstract**

This paper is a report of a professional development model designed to support and bring about changes in practice of mathematics in-service teachers while at the same time providing them with an accredited qualification from a university in the Eastern Cape of South Africa. The programme which has been in operation for more than a decade and a half is a three-year part-time course and takes places during school holidays. A problem which has existed for a number of years and is still prevalent in schools today is the lack of suitable and efficient professional development interventions in schools. The focus of incorporating this professional development model emphasizing an accredited qualification and then extending it into a collegial cluster programme places a strong emphasis on the personal and professional identity of the whole teacher in order to improve the learning of their learners. Collegiality is often described as a necessary requisite for professional development and is therefore central to improving teaching and learning.

The model situates the professional development of teachers in a context and is seen as a process. In this way, aspects that are associated with teaching include content knowledge, pedagogy, instructional tasks, the work of learners and classroom support are integral for creating possibilities for reviewing and analysing the situation.

Evidence of impact from our interventions indicate that classroom support visits and workshops conducted by the RUMEP staff show improvement in learner performance as reflected in the benchmark tests that learners of both experimental and control schools write annually. Cluster teachers have become reflective practitioners as a number of cluster teachers continually apply to register for the BEd (in-service) accredited programme. There has also been an increase in the number of learners who participated in the Olympiad and Horizon Competitions who get awarded certificates of merit. Some of the cluster teachers are used by their district officials in the Department of Education to train other mathematics teachers in mathematics content and other mathematics related issues.

**Key words:** *professional development, collegiality, in-service teacher, teacher identity*

## Introduction

The crisis in education in South Africa over the last two decades or more has been ascribed to the inadequate training teachers have undergone and the lack of support by Department of Education subject specialists. It remains a complex situation and although some non-governmental organisation do work in schools and provide professional development support to teachers, the impact is not readily perceived. A problem which has existed for a number of years in schools is the lack of suitable professional development of teachers' especially in-service teachers. These experienced teachers, whose qualifications have not been upgraded to the new approaches in teaching and who very often teach in far rural areas seldom receive any training or support to do their work adequately. According to Sykes & Darling-Hammond (1999) professional development is a key ingredient in improving schools and therefore teachers' practice.

There have been several definitions of what professional development is all about and Day (1999) gives a concise definition of professional development as a process by which either individually or with colleagues, teachers review, renew and broaden their commitment as change agents to the moral purposes of teaching, and by which they acquire and develop critically the knowledge, skills, planning and practice with children, young people and colleagues through each phase of their teaching lives. For professional development to be effective, it is argued by (Villegas-Reimers, 2003) that as a process it takes place in a context, and is situated in classroom practice.

In the past professional development took the form of one or two day's training in workshops (Villegas-Reimers, 2003) with teachers expected to go back to their classes and implement the strategies learnt. Very often the trainers were not subject specialists with the result that teachers fumbled and could not implement what they were supposed to learn. Teachers were not seen as active participants of their own professional development (Lieberman, 1995) with little interaction among other teachers. Teachers see professional development as separate from their daily regular work. This type of training has been severely criticized for being ineffective as it was very often not related to individual teachers' practice (Hawley & Valli, 1999). Teachers want learning opportunities that are meaningful and practical to them, involve reflection on their experience and include social and active learning (Glaythorn, 1990).

## Professional development and mathematics education reform

Mathematics education has been questioned nationally and internationally as the number of learners taking mathematics is declining. There has been recently a demand for a change in the way that professional development is implemented. It is argued that reform efforts in the past have not been very successful due to 'once off" workshops as alluded to earlier which teach basic techniques but do not look at teaching practices including planning, assessing, interacting with learners and the beliefs of teachers. Literature portrays that teachers teach how they were taught and that their beliefs are aligned to this phenomenon. The importance of teacher beliefs and teacher identity cannot be underestimated and need to be given more attention in professional development programs. Reflective teaching is receiving more prominence in education reform and has shown to play a significant role in the professional growth of teachers. Teachers recognise the complexity and necessity in their training. As each school environment is unique, attempts are made to encourage teachers to be critical of their work with the intention to effect change in their own classroom. In South Africa all teachers have to accumulate 150 professional development (PD) points over a three year cycle as part of their continuing teacher professional development and need to be registered as educators by the South African Council of Educators before they can start teaching. There are three different types of PD activities and these are teacher initiated, school initiated and externally initiated activities. How successful they are and when the three year cycle will be implemented remains to be seen. Some higher educational institutions in South Africa also offer a one year short course (face-to-face) for mathematics teachers especially those who teach in no-fee schools and where the performance of learners is poor. Research still needs to determine whether such short courses have any impact in the classroom.

There are only a few research studies that have documented the relationship between professional development on the one hand and student learning on the other (Garet, Porter, Desimore, Birman, & Suk-Yoon, 2001). As far back as 1993, RUMEP has been at the forefront of professional development in the Eastern Cape of South Africa and tried to show how the curriculum and its role in helping teachers teach properly, and their students' performance is crucial for success.

Collegiality has shown over the years that it is a necessary condition for success in any professional development model by placing emphasis on the professional and personal identity of the teacher. The RUMEP professional development model aims at developing critical, resourceful teachers who have the necessary confidence and enthusiasm to bring about change in their classrooms. It is hoped that such a cascade effect will be achieved as it filters down to all teachers in a school. In South Africa the curriculum has undergone a number of changes with the present one being implemented in 2012. This curriculum requires teachers to undergo a mind shift in their thinking as it requires them to incorporate new teaching approaches and not simply transmit knowledge. A learning centred classroom is being foreseen where the shift in focus is to the learner and learning with an emphasis on conceptual understanding, active learning, speaking mathematics, and addressing learners' errors and misconceptions.

The Rhodes University Mathematics Education Project (RUMEP) believes that in order for teachers to embrace the goals of reform in their teaching they have to develop a sense of success and self-worth as teachers and so for any change to take place new forms of professional development are needed that will affect teachers' actions and interactions in the classroom and lead to improved learning outcomes for all learners. Self-reflection and becoming a reflective practitioner is therefore seen as important in professional development and that self-knowledge is essential to self-change (Green & Smyser, 1996). We believe that we are on track in trying to improve the professional development of teachers by offering an accredited qualification which leads to sustained professional growth and development. What follows is a short description of our accredited degree course and the collegial cluster project.

**Bachelor of Education (in-service)**

The focus of the BEd programme is to develop confident and resourceful teachers who will inspire and assist the professional development of colleagues and most importantly, work to improve the quality of mathematics teaching and learning in their schools. The model of university-based training, followed by school-based support has over the years been tried and tested by RUMEP.

There are several key features in the programme that consist of important professional development strategies and innovations to address the challenges of reform in teachers' instructional practices. The programme considers the use of reflective practice to analyse teaching as an important component in the improvement of classroom practices. Through the reflections, teachers are engaged in self-examination that leads to self-improvement. The reflections help teachers to construct and refine their ideas about mathematics teaching and learning. Through reflection teachers take responsibility and participate consciously and creatively in their own professional growth and development.

Problem solving is also important because it can serve as a vehicle for learning new mathematical ideas and skills. This carries into the classrooms where learners are challenged to think and reason about mathematics, communication being an essential feature as learners articulate their thinking orally and in writing.

A number of teaching strategies and discussions take place during teaching sessions to create an environment that takes into consideration the needs of second language speakers to make the connection between the language used to teach mathematics and their construction of mathematical knowledge.

The course takes place over three years during school holidays and covers sixteen modules including curriculum studies, mathematics for teaching, professional development, research, auxiliary studies and preliminary studies including technology.

**Origins of the Collegial Cluster Project**

The Farm School Project which operated from 1994-2001 was a precursor to the Collegial Cluster Project. The Farm School Project was a programme developed by RUMEP in collaboration with the Department of Education in developing farm school teachers' skills in teaching mathematics in order to improve their teaching which in turn would improve the learning of mathematics. Indeed, the programme succeeded in achieving its goals, because all the teachers within the farm schools were developed. A change in terms of competence and content knowledge was observed from these teachers

With time, some of the farms were turned into game farms, which led to a reduction in the number of farm workers. Most of the farm schools were then closed down. RUMEP had to change the model of working in farm schools. The Collegial Cluster Project was then born in 2002 seeking to address the needs of mathematics teachers in rural areas within the Eastern Cape Province in South Africa.

The three-year BEd (In-Service) programme referred to above, works hand in glove with the Collegial Cluster Programme. The two programmes are inseparable; they are intertwined; one cannot exist without the other. When teachers complete their BEd studies, in fact even before they complete it, they are encouraged to form collegial clusters in their respective areas. These are communities of teachers, who come together to independently work on their own professional development. Some teachers at schools are either unqualified or under-qualified to teach mathematics, so these communities are of great help especially to such teachers. At such forums, teachers share their expertise through conducting workshops. They also share different meaningful strategies that can be employed when teaching mathematics. It is at such gatherings that teachers plan their lessons together. All these efforts aim at improving the teaching and learning of mathematics.

When other teachers within the districts or schools see what their colleagues are doing at the clusters, they develop an interest and join the clusters. Collegial cluster teachers, especially those who are underqualified are encouraged to join RUMEP and enrol on the BEd programme. All committed teachers heed the call and come and register with RUMEP. This, on the other hand, increases the number of qualified teachers, not only in the clusters, but within the Districts. This also addresses the shortage of mathematics teachers at schools. Some teachers are forced to teach Mathematics due to a shortage of mathematics teachers at schools and this has a negative impact on learner performance. It is some of these teachers that end up coming to RUMEP to register for the BEd programme. The fact that they have attained their BEd degree does not stop them from being cluster members. They continue being part of the cluster even after they have completed their studies. The teachers who cannot afford to come to RUMEP and further their studies due to family and personal commitments also benefit from the cluster activities. This therefore leads to the sustainability of the clusters.

The RUMEP Collegial Cluster Project also includes a MathsNet programme that focusses on equipping teachers with computer literacy skills and technology integrated into the teaching and learning of mathematics. During contact sessions, teachers are taught numerous mathematical and general programmes in order to assist them to be technologically literate. Teachers realise the need for change not only in their teaching approach but also in their teaching practice.

There are seven rural clusters that target 294 teachers and reach over 2900 learners that benefit from the Collegial Cluster Project. The targeted schools are Primary and Junior Secondary schools. The areas from which these teachers are drawn are very remote and getting to schools in these areas is a challenge as roads are all gravel and poorly maintained.

There are a number of activities that take place in the clusters and this keeps the fire burning. The activities are as follows:

**Benchmark Tests**

As a means of assessing impact in the collegial cluster programme, benchmark tests (pre-tests and post-tests) are administered to all the clusters. These assessment tasks are in line with the

Department's assessment criteria and they cover all the content areas and cognitive levels as prescribed by the Department in the Curriculum and Assessment Policy Statement (CAPS). The assessment tasks are administered to both control and experimental schools within the cluster.

The pre-tests are written at the beginning of the year, therefore it is through the pre-tests that learners' misconceptions and problem areas are identified. The results of the benchmark tests are given to all the schools that write the tests and are discussed with both the mathematics teachers concerned and the principals. They are also discussed with the Department of Education in the various districts through the Subject Advisors, so that they know about what is happening at the cluster schools. This kind of interaction with the teachers, principals and Subject Advisors helps them know where their learners are in terms of mathematics content knowledge. The pre-tests therefore do not only inform RUMEP's planning and intervention, but the teachers' and the Department's intervention and planning as well.

Benchmark tests in the form of post-tests are then written towards the end of the year to assess the impact that RUMEP's intervention had on teaching and learning at the clusters. The post-tests indirectly force teachers to keep checking their curriculum coverage, to make sure that learners are ready for the tests. The results from the post-tests are also shared and discussed with the various stakeholders such as principals, subject advisors in the various districts and cluster teachers.

**Workshops**

Workshops serve two purposes; some are conducted by RUMEP as per the areas identified during benchmark tests, while others are as per teachers' requests. Feedback workshops on the benchmark test results are conducted for all clusters at their respective districts. These workshops are attended by all cluster school teachers, even those who come from schools where the benchmarks are not administered. All the cluster schools that are neither control nor experimental schools are encouraged to administer the benchmark tests and mark them and report their findings at the feedback workshop. As some form of intervention, other workshops are done during the course of the year and this is where the misconceptions and problem areas get addressed. In addition to these workshops, cluster teachers also conduct their own workshops, based on their own needs.

**Lesson Study**

The Lesson Study is a teacher development practice that originated in Japan decades ago. Through the Lesson Study, teachers work together to plan a lesson based on a common goal to be achieved; and then one teacher teaches the lesson while others observe it. Afterwards, the team (presenter and observers) come together to reflect on the lesson with the purpose of refining and improving it further. Originally, the Lesson Study was used to improve the teaching and learning of mathematics and science in primary schools, however this focus has since changed as more countries adopt and adapt it to suit their needs. The Department of Basic Education in South Africa, like other countries, also adopted this practice. The aim is to improve not only the subject knowledge of teachers but also teachers' pedagogical content knowledge of mathematics and practice. In 2018 a Lesson Study seminar was held in the district where one of the collegial clusters operates. This was the second seminar to be held in the whole Province and it was done in full collaboration with RUMEP. The presenters came from three experimental collegial cluster schools and the lessons covered all the phases within the General Education and Teaching Band. The people in attendance came from all the districts within the Province and from the Provincial and National office. This is an indication that RUMEP does not do things in isolation, but in collaboration with the Department of Education. This has led to an improvement in lesson planning and practice especially in the cluster where the Lesson Study seminar took place. The use of the lesson study in other districts and clusters is gradually gaining prominence.

**Classroom Support visits**

As part of RUMEP's intervention in the collegial clusters, classroom support visits which are unusual in (in-service) education are conducted and they help us identify problem areas in certain topics. The main purpose of the classroom visits is to demonstrate lessons as per teachers' requests or observe lessons that teachers present. It is through classroom support visits that the curriculum coverage is monitored, because one gets a true reflection of what is happening in the classroom. Classroom support visits encourage teachers to reflect on their teaching, because at the end of every lesson, the teachers reflect on their lessons. Classroom visits also help RUMEP know and understand the conditions under which teachers work. Another aspect is to monitor the extent to which teacher are able to implement new understandings, strategies and pedagogies introduced in the course. Cluster schools are visited to deliver resource materials like maths sets, fraction circles and other resources that improve the teaching and learning of mathematics. An access into learners' minds and understanding is gained through classroom support visits. The visits are followed up by feedback sessions with teachers and principals and this has led to an improvement in teachers' practice.

**Provincial Mental Mathematics Quiz**

The Mental Mathematic quiz is designed to assess grade 6 and 7 learners' ability to solve mathematical problems mentally, without using a calculator or any other gadget. It is one of the ways of improving learners' mathematics computational skills. Mental mathematics encourages actual understanding, not just memorization. It has been observed from the classroom visits conducted that learners find it difficult to do mental computations. They cannot do simple calculations like "$7 \times 9$", they rely entirely on using their fingers or a calculator. In order to assist learners improve on their mental skills, cluster learners also participate in the mental quiz. The quiz takes place at circuit, district and provincial level. RUMEP's Collegial Cluster coordinator is often asked to adjudicate at the mental mathematics quiz and this gives RUMEP a broader sense of the mental skills of learners. This is another indication that there is strong collaboration between RUMEP and the Department of Education.

As our cluster schools are encouraged to participate in this quiz, the impact in many schools shows how cluster and BEd teachers have taken this important mathematics skill to heart and every year, some of our cluster schools reach the finals at provincial level.

## Mathematics Olympiads

The 2014 Diagnostic Analysis of the Annual National Assessment (ANA) revealed that learner performance in Mathematics in Grade 9 stood at 14%. It was against this background that RUMEP decided to introduce the Mathematics Olympiads in Grade 9. The administration of the Mathematics Olympiads is an annual event that occurs at cluster schools. The aim is to improve learners' problem solving skills as well as develop learners' mathematical content knowledge. In order to achieve this goal, the professional development of teachers is quite crucial. High quality training of mathematics teachers is important, because such teachers are able to equip students with critical thinking and problem solving skills. Mathematics Olympiads prepare learners for grade 10, where they choose whether to do Pure Mathematics or Mathematics Literacy. The other aim for administering the Olympiads is to encourage learners to choose Mathematics, which opens doors for better careers. Indirectly, the Mathematics Olympiads, to some extent addresses the shortage of skills in the country, because Mathematics is key to acquiring rare skills that the country needs. This is another way of how our interventions, impact on the cluster project.

## Results

### Impact of the Collegial Cluster Project and the accredited BEd course

The course which responds directly to the national and provincial needs of the country has positively impacted on those teachers who join one of the clusters as not only has their mathematical content knowledge improved, but their pedagogical content knowledge has had a major impact on their own classroom practice. Using lesson study as an example, experienced teachers have been able to share their thoughts and ideas and train and support less experienced teachers on the use of how to plan a lesson and to reflect on their teaching and their learners' work through taking the cluster teachers through what it means to become a reflective practitioner. The idea of the three modes of belonging referring to a community of practice (Lave & Wenger, 1999) such as engagement, which takes place on a continuous basis, imagination which involves engaging with the activities that have been planned and developing these ideas through the imagination that takes place. The third mode of belonging is alignment where teachers align themselves with the community through critically testing ideas and developing an understanding of new ideas such as the setting of the Mathematics Olympiad tests. Further, teachers have been able to arrange inter-school visits where they observe and critique a colleague's teaching which all adds to their own professional development.

The course has also elevated many of our teachers to positions of prominence after successfully completing the BEd course. A number of teachers have become Education Specialist Officers in the provincial Department of Education and have then acted as liaison officers to RUMEP in the establishment of new clusters.

Another major impact can be seen in the benchmark tests written by learners in the exit grades of 6 and 9, which act as another stimulus for teachers to improve their learners' performance.

Meetings are arranged with each cluster after the tests have been written to determine the shortcomings in certain topics which are then workshopped by the RUMEP facilitators.

The intervention of supporting teachers in their classrooms and workshops conducted by RUMEP staff has been evident throughout the years and is a major strength of our BEd course but also for the Collegial Cluster Programme. The improvement in learner performance each year is evident when matching our experimental schools with control schools in the same district.

## Conclusion

Professional development at RUMEP is embedded in a social context using multiple strategies which is in line with current learning –centred methodology and challenges teacher beliefs and current practices. The different activities described above showcase how and accredited programme remains aligned to a professional development model, namely the Collegial Cluster Programme. As each cluster aligns itself to a community of practice by testing and developing new ideas, the impact of such a teacher in-service model has a cross-cutting focus on other educational aspects such as the environment and HIV/AIDS and classroom management. The reflective nature of the programme interrogates teachers' thinking and their classroom practices which impacts on their own personal and professional identity. Teachers' views about the role of mathematics have changed. They acknowledge the significance of mathematics in the real world. Through the support that teachers receive from the project and their collegial communities, teachers have changed their thinking and become more confident to teach mathematics. This in turn has paved the way for more peer collaboration in a community of practice. Working jointly on shared goals has further complemented teacher independence. Collegiality has been beneficial as it has helped teachers to reconstruct their thinking after experiencing learning about new teaching strategies and built teachers self-esteem and self-efficacy.

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**Article 11**

## Intersection of religion and science: The influence of Christian values on STEM

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**Abstract**

Science, Technology, Engineering and Mathematics have taken over the world by storm. It seems like every innovation, discovery and principals have to be subjected to empiricism or rationalism. This storm is so strong that every institution is implementing STEM with great urgency and enthusiasm at fast rate. The ecclesiastical propagation of religious values seems to be outdated and discarded for losing relevance and significance in the contemporary society, even in Christian educational institutions. There seems to be no more place for abstract religious thought in the world of STEM. This paper thus posits; are Christian teachings of any significance to implementation of STEM? This work therefore sought to establish the importance of Christian values on STEM. It was guided by the intelligent design theory which posits that some of the complexities that exist in the universe can only be explained from the point of view of their being a designed pattern and a designer as opposed to randomness. The paper adopted the exploratory design to collect and present data. It entails studying the situation as it is in an attempt to explain it. The study instruments were document review and metasynthesis. This paper established that science and religion are not at war. They are just different ecosystems in the same community serving different purposes for a better society. This paper thus recommends that religious values should be taught alongside STEM and applied when teaching to bring about balance and sanity. This paper shall add to the existing pool of knowledge on promising approaches in the implementation of STEM.

**Key word:** *Christian values, Complimentary, Ecosystems, Religion, Science, Society, STEM*

**Abbreviations and Acronyms:** *IQ-Intelligence quotient, SDA-Seventh Day Adventist, STEM Science, Technology, Engineering and Mathematics*

### Introduction

Historically, religious believes used to be the origin of laws in both the biblical and African context (Edge, 2017). The challenging of such believes used to be heresy and thus unlawful. For example, in 1616 a book published in 1543 by Nicholas Copernicus titled “On the Revolutions of the Celestial Spheres,” was banned by the church (Hartner, 1973). The main reason for the move the church made was the fact that the book advocated for heliocentrism instead of geocentrism that was then thought to be religiously correct.

Geocentrism was a conventional astronomical model where the earth was thought to be the centre of the universe with the sun and other stars revolving around it (Goodman, 1995). Heliocentrism on the other hand upheld the now common knowledge that the sun was the centre of the solar system with the earth revolving around it (Goddu, 2010). Astronomers and physicists like Galileo, used to be openly persecuted by the church and forced to denounce their then alternative view that had been termed heresy (Liebreich, 2004). About 400 years ago, any scientific knowledge that challenged the religious norms was classified as heresy and rejected. The relationship of science and religion was that science was only acceptable if it helped advance the religious views or did not interfere with the prevailing religious views (Brooke & Maclean, 2005). It could have been said that religion was superior to science and science was merely a tool for nonbelievers to advance heresy against the church.

The modern view of science and religion has however diverted from the historical view. Science on one side has given rise to new discoveries, inventions and innovations. Some of these advancements have been used by theorists to prove religious believes wrong with an attempt to discredit religion. To this end, this paper thus posits; Is Religion out rightly outdated and irrelevant in the world of STEM? It thus sought to establish the importance of Christian values on STEM.

Science has come up with principles, laws, standards and theories that sometimes out rightly challenge the religious standpoint of knowledge. For example, after Charles Darwin and Alfred Russel Wallace (1958) advanced the theory of evolution, promoters of the theory started presenting it as an alternative reality to the story of creation as presented in the bible. According to Strahler (1987), This created controversy that exists to date. In fact, there are religious parents who refuse to take their children to school out of fear that they will be taught evolution and challenge their religious faith. Some scholars like Pennock (2010), even examine the possibility of students being allowed to opt out of being taught about evolution as part of their curriculum.

With time, due to the premises in proof and the duplicable scientific methods and design, science has slowly moved from just being a tool of advancing heresy against the church into a reality through which the world is approached and understood (Brooke, 1991). Science has become mainstream with its theories, laws and principles (Finson, Ormsbee, Jensen& Powers, 1997). It has become part of the modern culture and thinking where both new and old knowledge must be subjected to scientific methods and a decision made as to the validity of the information. There is a science for almost every phenomenon and aspect of the modern world. Authors like Smart (2015) and Muller (1873) have even gone ahead and written about the science of religion.

Because of the fairly constant and fixed nature of religious beliefs, it has become almost impossible to compare religion to the dynamism and ever-changing nature of science. Whereas science promotes research-backed and proof-based views and facts, religion depends on faith and the ability of one to believe without question. This conflicting existence between the two is sometimes best brought out by the phrase ‘Faith and reason’ as used by scholars like Taylor (1985), Swinburne (2005) and Habermas (2010). There are positivists like Helm (2000) that prefer to use the phrase ‘Faith with reason’ instead.

Science has now taken over the world by storm and religion is slowly losing the tight hold and respect that it once held when it came to the development and the understanding of the world and how everything within the world works. Everything these days have to be subjected to empirism (Carnap, 1952) and rationalism (Miller, 2015).

This goes directly against what religion is all about. There seems to be no more place for abstract religious thought in the modern world. This is why it is important to determine in the modern world context the point where religion and science intersect. In article, the influence of Christian values on science have been discussed.

## Research Methodology

This was mainly an exploratory study as explained by Stebbins (2001) seeking to determine the relationship between science and religion in the modern world. All the data and information used for this study was secondary in nature and was derived from the synthesis of already available literature and knowledge. Documents review and metasynthesis was therefore the main methods of obtaining the data that was used to put together this article.

The study was guided by the pseudoscientific intelligent design theory (Dembski, 1997). Whereas the theory does not openly support creation as advanced by religion, it uses reason to analyse the complexities and strategic relationships and designs existing in the universe to rule out evolution and natural selection as the main origin of the universe. It then further hints at there being an intelligent designer that some authors like Moreland (1994) eventually refers to as God intelligent design although having several critiques (Greenspan, 2002; Shanks, 2004; Sober, 2007) it relies on scientific facts to develop theories about religion and origin. The Religious base of this design does not affect the quality of science, neither does it negate the secular

## Discussions

### Religion versus Science

Religious beliefs neither affect the quality of science nor do they negate the secular. Religion deals with origins through faith and divine revelations while science explores origins from observations about nature. Whereas science attempts to theoretically determine the origin of everything through fundamental principles and laws, religion already knows the origin of all thing and is thus constant in its premises (Cruz, 2017).

The being constant even in light of ever-changing new information and reality is why sometimes science seems to be in a state of friction with religion and faith-based beliefs. Nothing seems to be challengeable in the religious realm. In fact, holy books like the bible have verses that strictly forbid anyone from changing and challenging the words therein (Revelation 22:18).

The only open avenue of approach in such religious references is analysis and interpretation. This open avenue has led to the conflict amongst believers within their own doctrines and across doctrines. The different interpretations and analyses of the religious texts have led to the segregation of faith and the believers. For example, different churches and sometimes cults have been started, advanced and made popular based on the different interpretation of the bible. A common example is the interpretation of the seventh day when God rested in the bible. Some Christians believe it to be Saturday whereas others prefer to think of it as Sunday. These varied interpretations alone gave rise to the Seventh Day Adventists (SDA). The Quorn and the Bible have almost the same origin but is interpreted differently leading to two different religions (Elster C.A, 2003).

Science then comes in and start questioning the authenticity of religion in view of the fact that there are so may interpretations of the same religious texts and so many different churches as a result of the interpretation. Science also challenges the never changing nature of religious information. Some scientists argue that religious books like the bible were written during the era of limited information about the world and the universe and must therefore be selectively accepted as the truth or totally subjected to scientific methods for authentication.

Religion on the other hand looks at science as an agitator out to discredit faith as the fundamental aspect of religion. Science always seems to have alternative theories about phenomenon that would in the normal religious realms be termed as miracles from the Creator. If someone is healed through faith, science might say that the person would have been healed even without the faith because the ailment was biological in nature and thus plays to the tune of science. Science would even go further and isolate the ‘pathogens’ responsible for the illness and provide a prescription remedy to the pathogens.

If someone like the very popularized Mama Rosa is raised from the death in the religious realm, science will start by questioning the authenticity of the death even before the methodology used to raise that person from the death. It will require a duplication of the action in order to acertain the authenicity of the claims. The same person will then be asked to raise another person from death or give the clear steps that one can use to raise someone from the death.

Religious theorists see science as a weak attempt towards explaining what religion already knows. Science is seen as inefficient and redundunt beyond certain dimention where reason no longer applies. In fact, there are so many thing and aspects of the universe that science still has not found a way of explaining in an accurately precise way. Intelligent design theorists for example looks at the very detailed aspects of life like the DNA and the universe and rule out the randomness and natural selection theories that science subscribe to.

Such theorists put science against itself because the very discomveries made by science sometimes challenges the besic scientific norms, theories and principle. That is why whereas theorists like Charles Darwin do not support the idea of intelligent design (Sulloway, 2009), scholars like Ayala (2007) surcastically mock him for having discovered the intelligent design without the designer.Some scholars like Dawkins (1997) even look at science as a form of religion on its own. It is these and more historical aspect that have arisen a cold war between science and religion with each trying to prove its dominance over the other.

## STEM and the Mordern World

The mordern world has become scientific in approach.Science, Technology, Engineering and Mathematics (STEM) have become the standards of mordern inquiry and thinking (Gonzalez & Kuenzi, 2012). In America and other parts of the world, children are exposed to STEM at a very young age (DeJarnette,2012). This early exposure to STEM usually coincide with their early exposure to religious believes as well (Harris& Koenig, 2006).

Children are then taught about what we already know about the world, science and religion. After the religious education teacher for example finishes teaching creation in one lesson, the sciecne teacher steps in and teach about evolution in the next lesson leading to the great debate between creation and evolution with respect to teaching (Keith,1982).

Because STEM seems to put forward more verifiable theories, laws and principles, it then follows that children will be more likely to be biased towards 'having more faith' in science than religion. The term 'faith' here is used to imply that even believing in science requires faith.

STEM has led to inventions, innovation and continuous revolution of knowledge. This has made it by default a standard in institutions, organizations and other bodies of knowledge. Almost all institutions are incorporating STEM in their designs with great urgency and ethusiasm. The ecclesiastical propagation of religious values seems to be outdated and discarded for losing relevance and significance in the contemporary society, even in Christian educational institutions.

## Christianity and STEM

Are Christian teachings of any significance to implementation of STEM? For starters, science on its own does not usually have concrete laws to abide with. There are some researches and discoveries in STEM that have made earth a dangerous place to live in.

For example, the atomic bomb by Albert Einstein and Robert Oppenheimer(Einstein,1947) was made with fear that the Germans were already working on a similar bomb. The idea was to protect the United States in case the Germans succeeded in their then futile endeavours (Einstein, 2013). In 1945, the bomb was used in Hiroshima and Nagasaki killing a total of between 129,000 to 226,000 people (Loewe & Mendelsohn, 1981).

Mikhail Kalashnikov, creator of AK-47 wanted to give the Russians an upper hand in war. Instead he ended up creating a weapon that would cause more deaths around the world than any other weapon (Chivers, 2013). Even noble inventions that were meant to help people like the paper spray by Kamran Loghman (Sams, n.d.), was weaponized and militarized.

People have been using science for economic gains for a very long time. Alfred Nobel for example had over 355 inventions that he merchant for wealth. One of these inventions was dynamite that was used for mining and had caused a lot of deaths through accidental detonation in mines (Nobel Prize, 2012). In 1888, Nobel's brother Ludvig died and a newspaper in France wrongly reported it as Nobel's death. The headline for the paper was 'the merchant of death is dead' (Benjamin

Jr,2003). This made Alfred Nobel rethink his legacy and set up the Nobel Prize to try and undo the wrongs he had done long after his lifetime.

Disturbing researches on human beings like Project MKUltra (Hearing, 1977), Dr. William Beaumont and the stomach tests (Numbers, 1979), electroshock therapy on children (Bender& Keller, 1952) and syphilis experiments in Guatemala (Rodriguez& García,2013) only serves to show that STEM values the advancement of knowledge more than human life.

STEM does not usually have limits as to what is right and what is wrong. STEM focuses on solving a particular problem that sometimes happens at all cost. STEM therefore relies on the regulation by law and religious principles. STEM issues are however very dynamic that the law usually has to be updated all the time to deal with emerging issues in STEM.

This thus leaves religion as the surest regulator of STEM and the principles enlisted therein. In fact, most laws that regulate STEM or counter the negative effects of STEM usually come from religious activists before picking up as part of the politics and the law. There is an entire field of ethics that is meant to give STEM a conscience during the research and experimentation processes. Ethics however has most of its foundation from religious principle of right and wrong and therefore create grounds that help when religion and science interact.

One of the religions contributing to ethics is Christianity. Having sound Christian values automatically inculcates an aspect of ethics in STEM and lead to respect for life and discoveries only intended for the betterment of life. Christian values have the potential of introducing self-regulation in STEM and improving the quality of research and discoveries. For example, Einstein will never have invented the Atomic Bomb had he applied the Christian values of respect to life. In fact, he even regretted the invention later on after he saw the mayhem he had caused.

STEM should not always be about the verifiable and the empirical, it can include the spirituality as well and still coexist. It is not always about what is real and what can be proved. Sometimes life must be approached from the dimension of faith and belief.

**Is Science at War with Religion?**

This paper established that science and religion are not at war. They are just different ecosystems serving different purposes for a better society. The apparent war is sometimes brought forward as a result of dramatic literature intended to magnify the simple misunderstandings between science and religion. In Africa for example, you can find a scientist who is a Pastor. The science is practiced during the week whereas religion comes into play during the weekends. In fact, some of the earliest scientists were Christians, for example, Isaac Newton, Rene Descartes, Galileo Galilei, Corpenicus, Leonardo da Vinci, to name but few (CUO, 2019). You will find scientific conferences starting off with a prayer. You find the same teacher teaching both science and religion and switching accordingly and correctly as per the subject and syllabus. 'We treat and God heals' is one of the most common quotes you usually find in hospitals. This means that you can apply the right scientific remedy but it proves futile. What all this proves is that both science and religion are important and play different roles in human societies.

It is not strange to find Christians standing at the pulpit using the microphones, the speakers, the pianos and the guitars that existed as a result of science while talking against science. It is very common as well to find modern scientists excited about proving religion wrong. Some even argue that the Bible was written during a phase of civilization when human beings were ignorant and must be treated as such. These are just outliners in the entire peaceful coexistence between science and religion and should be treated with a light note. Science without Religion is lame and Religion without Science is blind(Einstein,1930).

**Jesus, the Example of Christian Values**

Jesus is the author of Christianity and he was a great teacher himself. He taught his disciples values both in word and in deeds. He applied the same throughout his ministry when dealing with his disciples and this won him admiration and a great following for that matter.

To begin with, Jesus was compassionate (Mathew 9:36). Teachers should be compassionate when dealing with learners. They come from various backgrounds and have different levels of intelligent quotient (IQ).

Jesus was also very loving. There is no greater love than laying down his own life for the salvation for his disciple's humanity as a whole (John 15:13). When a teacher loves the students they tend to trust in him or her and open up. This means that they stand a better chance of receiving help pursuance of STEM.

Another value is commitment despite the many obstacles. Many are the times the Sadducees, Pharisees and the scribes rose up against him when he was doing good but he remained focussed on his calling. Teachers are also not supposed to succumb to exterior negativity, be they from leaners themselves, parents or any other personality.

A servant-hood spirit is also very vital (Mark 10:45). This is demonstrated when he washes the disciples' feet. Likewise, tutors must be willing to serve their clients regardless of their status in the society. Tutors should be forgiving (Luke 23:34). Learners make many mistakes in the process of learning therefore harbouring grudges can hamper the acquisition of STEM knowledge (Mathew 5: 38-40). Gentleness is another value that Jesus taught in action. Children loved and he loved them back. At one point he told the disciples to let children go to him. On the other hand, cruelty will drive away the learners thus making them to benefit less from STEM.

Jesus was patient with people who doubted him, his followers inclusive. Likewise, teachers should be patient with the learners. a tutor should be slow to anger in order to accommodate the various students' personalities. Closely related to this value is self-control. After fasting for forty days, Jesus did not yield to temptation. This comes in handy especially when a teacher is provoked beyond measure. It also keeps teachers from carnal knowledge and sexual harassment of their students.

A tutor should be humble thus not working for a show and not demanding accolades for his or her exemplary performance (Proverbs 17:7). Teaching is more of a calling than a profession parse. A teacher should always work as unto God. A teacher should not be judgemental (Mathew 7:1-5). Instead should be very understanding since learners have both strengths and weaknesses.

Teachers are encouraged to be an example to their learners by practising what they teach. They are not supposed to preach water and drink wine (Mathew 23:27-28). In the same vein, a tutor's morality should also be worthy emulation (1 Corinthians 6: 19-20). Another value is wisdom which is important to both the learner and the tutor. It essential in making sound judgement and making the right decisions.

There are other values which Jesus taught which can be inculcated in learners to make them better STEM scholars. This include; endurance, justice, creativity, peace, hope, respect, honesty, generosity, obedience, to name but a few. They help any learner to remain balanced. Conclusively, teachers will be judged harshly if they know the truth and don't apply it James 3:1).

## Findings

This study established that Science and Religion are not at war but complimentary. They are both different ecosystems serving different purposes in the same society. This work confirmed Einstein's words that Science without Religion is lame and Religion without Science is blind. The Christian Religious values are thus valuable and should be inculcated in the learners and incorporated in the implementation of STEM to bring about balance and sanity since Religion is the conscience of the Society. The Christian Religious values are non-toxic or rather don't have a negative effect on STEM and there can never be an over-doze of the same. Religion relieves stress from the elaborate STEM procedures and especially the rigorous ones. Religion is a breather.

## Conclusion

From this article, it is important to take away that religion and science are inseparable and thus depend on each other; they are not at war. It is also important at the same time to note that religion and science are both different ecosystems in the modern human society where people are both scientific and religious in nature. This is particularly true in Africa where the line between religion, science and traditional beliefs is so thin and can be automatically crossed without any conflicting thoughts. Summarily, Religion is the conscience of the society (Williamson ,2017).

## Recommendations and the way forward

Christian values should both be applied in the practical teaching and implementation of STEM and also inculcated in the learners in order to bring about sanity in the modern society through balanced acquisition, dissemination and application of knowledge and skills

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**Article 12**

# Effect of lesson study on students' performance: The case of secondary mathematics students in the rural-mountainous area in Lesotho

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**Abstract**

Mathematics is an important subject as it paves way into learners' future. However, performance of mathematics in Lesotho secondary schools is not satisfactory. Learners mostly affected are those in rural areas.

The purpose of the study was to investigate the effect of LS on learners' performance in mathematics. The study followed mixed methods design where three mathematics teachers from rural school were studied. The sample consisted of grade 10 learners. Data was collected using records from ECoL and through teachers' interviews. Learners' performance was analysed statistically using charts. Interviews were analysed thematically.

Findings showed that learners' performance during the year in which LS was carried out improved and teachers' content and pedagogical knowledge also improved. However, teachers' main concern was that LS was time intensive. The recommendation is that LS be used in the teaching of mathematics especially in schools in the rural areas.

**Keywords**: *Mathematics teaching/learning, performance, lesson study, professional development.*

**Abbreviations:** *ECoL- Examinations Council of Lesotho, LS – Lesson study, MoET- Ministry of Education and Training*

## Introduction

Mathematics is one of the most important subjects in the school curriculum as learners will need it for the rest of their lives. It is also a subject that is needed for the development of any countries as it is essential for understanding other disciplines such as arts, business, science and technology. Everything in real life requires the use of mathematics in one way or the other. Sa'ad, Adamu and Sadiq (2014) sum up the importance of mathematics by highlighting that mathematics relates to everything in the universe from the smallest to the largest. However, mathematics is one subject that is mostly feared by learners in the schools and they often struggle in understanding it. Russel (2008) in Mills (2010) asserts that learners lack confidence in doing mathematics which instills fear that mathematics is too hard or fear of failure and fear that one cannot be able to do it. This seems to impact negatively on their performance in mathematics.

The performance of mathematics in Lesotho secondary schools, like in other countries has been poor at all levels especially in the rural areas. Mogari et.al (2009) observed that there is a continual poor result produced in mathematics in the Lesotho schools. This is happening despite the fact that mathematics is awarded more hours in the schools' time-table than other subjects in Lesotho. Similar trend has been observed by Enu et.al (2015) who illustrate that students' achievement in mathematics in Ghana over the years has not been encouraging at all levels. Poor performance in mathematics is even worse in the rural areas where there is lack of resources. According to Ajai and Imoko (2013) schools in the rural areas are mostly affected is that there is lack of use of lack of resources and qualified teachers. The study conducted by Nenty (2010) in Lesotho revealed that there has been a continuing decline in the quality of education at all levels, especially at secondary level where the rate of pass had declined especially in mathematics. The status quo has resulted in a critical shortage of tertiary learners for scientific and technical training in which mathematics is required as a core subject for such training.

According to Mathibeli and Maema (2005), the performance of Lesotho learners felt well below the average, with scores of 447 on mathematics while the average score was 500. Furthermore, reports by the Examination Council of Lesotho (ECoL) also show serious deficiencies in mathematics performance. In an attempt to address this status quo, the Ministry of Education and Training (MoET) introduced numerous initiatives in the form of professional development programmes that were meant to assist teachers in the teaching of mathematics. The belief is that initiatives that are targeting teachers are important as teachers have the most direct contact with their learners and also have considerable control over what is taught. Therefore, improving teachers' knowledge and skills which are subject to deterioration after some years of pre-service training is an important factor towards improving learners' learning and achievement (King & Newmann, 2001).

For Kaur, Kwon and Leong (2016), efforts to improve learners' opportunities to learn mathematics cannot succeed without parallel attention to their teachers' opportunities for learning. Thus, teacher professional development is a crucial element in an effort to improve learners 'performance in mathematics and also to improve teachers' teaching knowledge and pedagogical skills. However, in the situation of Lesotho, teacher professional development programmes introduced by MoET have not shown any positive improvement on learners' performance in mathematics. For Petri and McGee (2012) and Seyoum, (2013), professional development programmes which do not show any improvement on teachers' teaching practices are those that come as one-shot workshops where the presentation is done by an expert to a large group of teachers and pay little attention to the individual needs of teachers and the context in which they are. Researchers such as Darling-Hammond (2003) have observed that the type of professional development programmes offered to teachers in high-achieving countries have some of the following features: they are sustained over time, involve active learning and collaboration, context-based and content-focused (Murray, 2014). The purpose of this study is therefore to investigate the effect of Lesson study (which has the similar features of professional development programmes mentioned above) on learners' performance.

**Literature Review**

In an endeavor to establish the effectiveness of high-quality professional development programme that has features such as collaborative, reflective, contextual, ongoing, build new knowledge and skills, lesson study as a form of professional development programme that has these features will be discussed. For Murata (2011), lesson study incorporates many characteristics of effective professional development programmes such as site-based, practice-oriented, focused on learners' learning, collaboration-based and research-oriented.

**Lesson Study**

Lesson study was originally developed in Japan as an educational practice in which teachers, in collaboration with lecturers and Japanese experts, tried out some teaching models where teachers were reflecting and promoting the new paradigm of the secondary mathematics and science education. In this model, learning activities are not only perceived pragmatically and are short time oriented, but they also can be perceived as a long-life time purpose (Marsigit, 2007). Perry and Lewis (2009) define lesson study as

*a cycle of instructional improvement in which teachers work together to: formulate goals for student learning and long-term development; collaboratively plan a "research lesson" designed to bring to life these goals; conduct the lesson in a classroom, with one team member teaching and others gathering evidence on learner's learning and development; reflect on and discuss the evidence gathered during the lesson, using it to improve the lesson, the unit, and instruction more generally, (p.366).*

Based on the definition given above, lesson study has three stages. The first is collaborative planning, followed by conducting and observing the research lesson and finally feedback and reflection on observed lesson. Burghes and Robinson (2010) illustrate that during planning session which marks the first stage, teachers deliberate on the learning goals and content to be taught and how it should be presented. Elaborating on the second stage of LS, they indicate that teachers actively embark in the process of actual teaching where one teacher teaches the lesson while others observe and take evidence of learners' learning. For Ferreira and Ono (2010), in this stage, teachers who observe the lesson listen attentively to all contributions made by the learners and make a note of critical remarks by and/or behaviors of the learners in relation to achieving the lesson objective. In the process, teachers are able to develop a common understanding of what good teaching practice involves. In the third stage, which happens after the delivery of the lesson, teachers reflect on the lesson by checking at whether the learning objectives have been met, what were learners' reactions to the lesson, what were the strengths and challenges of the lesson and how the lesson could be improved (Ferreira & Ono, 2010)

### Impact of Lesson Study to Teachers and Learners

Lesson study is not only about producing a well-planned lesson, but it is also about building capacity of teachers, their expertise and knowledge base. For Meyer and Wilkerson (2011) an academically rich environment begins with teachers who are knowledgeable in mathematics, knowledgeable of learners, and knowledgeable of instructional strategies. Shulman (1986) calls these types of knowledge content, pedagogical and pedagogical content. In other words, for teachers to teach more efficiently and effectively, they need to understand the content they teach, how to pass it to the learners and how learners acquire that content. Murata (2011) illustrates that teaching is viewed as an interactive process in which learners' learning and content come together through effective teacher facilitation. He further points out that this interactive teaching requires teachers to know how learners typically think and express their understanding so that teachers can effectively facilitate their learning by weaving together different ideas. In addition, he demonstrates that the focus on learners' learning binds different parts of the lesson study cycle, as teachers identify goals in terms of learner's learning of the topic, investigates curriculum that teach the topic, plan a lesson to make learner's learning visible in the classroom with the topic, gather data in the lesson, and, afterwards discuss the learner's learning that occurred during the lesson.

According to Fernandez (2005) in Murata (2011) different types of knowledge come together and interact with one another during LS. In the process, teachers get the opportunity to examine and deepen their understanding of mathematical content, and to build effective strategies for teaching mathematics.

Lesson study is not just about improving teachers' knowledge base but it also improves the overall teaching/learning process, as it takes learners thinking into consideration. For Collet (2019) teachers in the LS team look closely at what learners are learning, identify their misconceptions and design ways to address these misconceptions. According to Han and Huang (2019), studies carried by Lewis and her team revealed that LS improved teachers' mathematical knowledge and also increased learners' standardized scores in mathematics. In addition, Burghes (2010) illustrates that LS also enhances learners' motivation, confidence, and participation thereby increasing their performance.

Though LS has been found to have numerous benefits, research reveals that it has some challenges. Lesson study has been found to be time consuming as it requires teachers to come together for planning and searching for resources/ideas which will be used during teaching of the research lesson. In most cases, this adds an extra load on teachers' part as they are already tight down by heavy workloads (Lim, 2006; Mesfin & Rustaman, 2014).

### Methodology

In this study, a mixed methods design was used to gather data. Johnson and Onwuegbuzie (2004) define mixed method design as the class or research where the researcher mixes or combines quantitative and qualitative research techniques, methods and approaches into a single study. The study used mixed methods design in that data was collected through analysis of learners' performance in national examinations over a period of three years and also through teachers' interviews. The study lasted for a period of one year after which the interviews were carried out. The quantitative analysis was useful in providing an overall picture of learners' performance in mathematics (Cai, Mok, Reddy & Stacey, 2016). On the other hand, qualitative data was useful in obtaining teachers' insights about LS process.

The participants in this study consisted of three teachers who were teaching mathematics in one secondary school in the rural area.

They comprised of one female and two male teachers. The female teacher had a Diploma in mathematics and Science Education; one male teacher had a Bachelor of Science Education while the other had Bachelor of Science. The school had a roll of 178 learners. Due to the location of the school, most of the male learners were not attending school regularly as they sometimes had to look after animals. Lesson study was carried out in grade 10 which had a total of 49 learners in 2017.

It should however be noted that a sample of three teachers raises a concern with regard to generalisability. Having practiced LS with only three teachers does not allow for generalization of results to the wider contexts but can only be used inform other studies.

**LS Process**

Prior to implementation of LS, teachers were trained on lesson study process for one day by the researchers who learned about LS in Singapore and Japan. After training, the researchers and the teachers sat together and prepared a series of research lessons that were to be taught for one week (three 80 minutes lessons and one 40 minutes lesson). The first three double lessons were taught by the researchers in turn and the remaining single lesson was taught by one of the teachers. The purpose of the researchers was to familiarize teachers with LS process and also to show them how evidence of learners' learning is collected using a designed schedule. Thereafter, teachers were left on their own to practice LS and researchers would come only once a month to check on them or whenever they were requested to come.

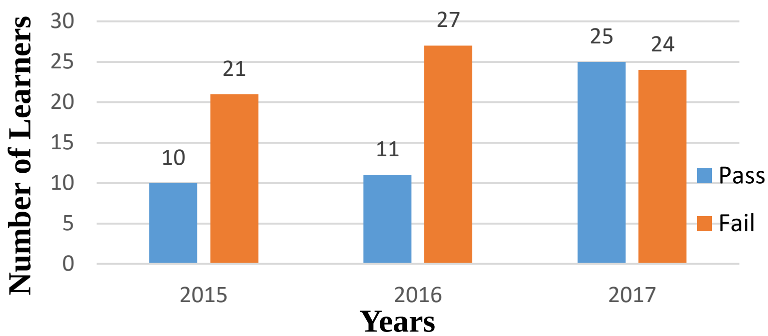
At the end of the year, teachers were interviewed on how LS impacted on their teaching practices and their learners' learning. This was done while waiting for the release of the national examination results for 2017. After the results were out, learners' results of the national examination for the two previous years and the year in which LS was carried out were compared. Data that were collected from teachers' interview was classified into *Benefits of LS to both Teachers and Learners,* and *Challenges faced by Teachers in Implementing LS.*

## Findings

Data on learners' performance in mathematics in national examination for the years 2015 to 2017 were compared and the results are shown in the chart below. The results were classified into pass and fail, where symbols A to E indicate a pass and symbols F to G indicate a fail.

**Figure 1**

**Maths Results in National Examination**




Data show that in 2015, 10 out of 31 learners who sat for the national examination got a pass in mathematics which accounts for 32%. In 2016, 11 out of 38 learners passed the exam and this is only 29% pass. In 2017, 25 out 49 learners passed. The percentage of learners who passed mathematics in 2017 was 51 and this was the year in which LS was practiced. These results showed a tremendous increase in the percentage (22%) of learners who passed mathematics in the year in which LS was practiced compared to the 2016 while the percentage increase from 2015 to 2017 was 19%.

**Table 1**

**Grades Obtained by Learners in National Examinations**

| Year | Grade A | Grade **B** | Grade C | Grade D | Grade E | Grade F | Grade G |
|---|---|---|---|---|---|---|---|
| 2015 | 2 | - | - | - | 8 | 7 | 14 |
| 2016 | - | - | 1 | - | 10 | 5 | 22 |
| 2017 | | 1 | 4 | 4 | 16 | 13 | 11 |

*Note*: Pass Grades are from A to E

Fail Grades are from F to G

The results showed that in 2017 when LS was practiced, 9 learners obtained better grades, B to D, as compared to other years. Generally, the overall quality of the grades in 2017 improved.

Data collected through interviews were classified into two themes which will be discussed below:

**Theme 1: Benefits of Lesson Study to both Teachers and Learners**

Teachers who participated in this study reported that LS helped them to fill the gaps in their knowledge as they developed new insights about content. For example, one teacher pointed out that *there are some mathematics concepts which the teacher may think that he/she knows them, only to discover during preparation of research lessons that he/she did not fully understand such concepts…* Similarly, another teacher alluded that *teachers in my team have helped me to look at the content from different angles, during planning, my colleagues came up good ideas that clarified some of the mathematical concepts that I could not have seen on my own.*

Furthermore, teachers who took part in the study confirmed that their engagement in LS process improved their pedagogical practices. Elaborating on how LS improved their pedagogical practices, one teacher said *I now have simpler techniques of teaching mathematics which I gained from my colleagues. Participating in lesson study has really improved my teaching…*

The same sentiments were shared by another teacher who confirmed that:

*Even the way I prepare my self is different from what I used to do, I prepare in a different manner as I now have to look at different ways of presenting content and also to anticipate what kind of questions learners might ask.…*

Elaborating further on the importance of LS, one teacher illustrated that "*when I was teaching, other teachers were able to help with concepts which I could not elaborate clearly to the students as they would chip-in to fill the gaps*"

Commenting on the effects of LS on learners, teachers illustrated that LS enhanced learners' participation. One teacher demonstrated that *learners are participating more than before… even those who never participate are now actively involved in discussions…*

**Theme 2: Challenges faced by Teachers in Implementing LS.**

Though LS has been found to have many benefits to both teachers and learners, but it also has some challenges during its implementation. Teachers in the study had a feeling that though lesson study has helped them to improve their practices, but the issue of time was a problem. One of the teachers said

*To be honest it consumes time, it is not in all the cases where teachers are able to attend, though we do not prepare a research lesson for every lesson. It is about timing- as teachers are preparing a research lesson and observing, learners in other classes are left unattended*

## Discussions

In general, there seemed to an improvement in the learners' performance in the year in which LS was practised. Furthermore, there was also an improvement on the quality of the grades learners obtained in the mathematics national examination.

The results of the interviews showed that LS improved teachers' content knowledge and their pedagogical knowledge. These results confirmed what Fernandez (2005) in Murata (2011) has reported. In addition, the results of the study also indicated that learners' participation increased as a result of LS being practiced in their classroom. These results also resonated with what Burghes (2010) observed. However, the findings revealed that teachers worked as team in presenting the research lesson which is contrary to what LS process stipulates.

Time factor came out to be one of the challenges facing teachers when implementing LS in their classrooms. The issue of time seems to be a major concern to those who implement LS. As indicated, Lim (2006), Mesfin and Rustaman (2014) are also of the same view.

## Conclusion

The study showed that LS had a positive impact on both teachers and learners. Teachers in the study improved in their content and pedagogical knowledge which in turn impacted positively on learners' performance. Learners' performance in the year in which LS was practiced improved drastically. The study brought the new insight in the effect LS has on teachers in that it could also be used as form of team-teaching especially in situations where teachers have some gaps in terms of content.

It has been established that LS does not only improve learners' performance but it has also improved the quality of grades. This is evidenced by improved overall performance which shifted from lower to higher grades.

In an endeavor to improve learners' performance in mathematics which is currently of a concern, Lesotho could adopt LS in the secondary schools especially in the rural areas where teachers are less qualified and there is shortage of resources. However, as teachers had indicated, this could work effectively if school administrators could also commit by allocating time in the time-tables for LS sessions.

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**Article 13**

# The constitution of a mathematics explanation in Botswana secondary schools

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**Abstract**

This study reports on research that explored what constituted a mathematics explanation. Participants in the study were five mathematics teachers selected from five different secondary schools in one of Botswana's eight districts. Teachers were selected purposefully in accordance with the way the schools performed in the national mathematics examination. The problem for the study was to gain insight into the different or similar ways in which teachers explained the same mathematical concepts to learners. Literature of research on mathematics teaching quality suggests that the teaching quality is underpinned by what is privileged in the teacher's explanation. The mathematics that learners get to learn resides in the explanations offered in the classroom. Thus, the qualitative difference in what learners learn is associated with what teachers choose to explain or not explain. The performance on national examinations stands in contrast to Botswana's aspiration of a knowledge-based economy which relies on science, technology and mathematics education. Therefore, exploring what goes on inside mathematics lessons is critical for policy and teacher professional development. It was found that professional development is important. The research question for this study was stated as: What is the nature of teachers' mathematical explanations?

**Key words:** *Learners, Mathematics Education/teaching, Learners, Professional Development, teaching quality*

## Introduction

Mathematics is viewed as an important subject in the 21st century. It is a daily bread because it appears in the many ways of our daily life because its principles appear in issues such as insurances, patterns, finance, technologies and economics. According to Dalal (2008) defines mathematics as a universal language and a way of thinking which all will need, in small or large measure, to make sense of the world around. Mathematics education deals with the teaching and learning of mathematics together with the necessary tools (steps, procedures) that they are required for the teaching and learning.

Charles and Lester (1982) define mathematics education as: The study of the subject should have potential for enriching the students' lives in some way.

Mathematics education in Botswana has been described as being in parlous state at all levels of the education system (Pendali, Ogunnyi & Mosothwane,1993) and in the majority of cases, teaching in Botswana classrooms is teacher-centered (Snyder and Fuller,1991; Prophet and Rowell,1990) in Mapolelo (2001).

**Purpose of the study**

The main purpose of this study is to prove/show the importance of the legitimation on teaching and learning of Mathematics. The results will be shared with the following:

a) Policy makers

b) Educators

c) Educators/Teacher developments departments

d) Curriculum development and Implementers departments

**Research questions**

Research questions should not be questions that require yes or no answer (Selamat 2008) in Nenty (2009). The main research question of the study is:

a) What is the nature of teachers' mathematics explanations?

**Significance of the study**

The study is an external evaluation and therefore will give non-biased findings and will help to see external factors attributed to the lack of good mathematics teaching and learning. This study will be of help to the following;

a) Policy development and Implementers

b) Teachers and other practitioners

c) Parents, Government and other stakeholders

d) Students/Learners

**Limitations**

According to (Isaac and Michae,1990) argues that what limitations exist in the researcher's method, design or approach, sampling restrictions, uncontrollable variables, faulty measurements, and other compromises to internal validity. The few schools were chosen randomly in Central Districts in Botswana hence the results cannot be generalised

**Delimitations**

The schools and classes were chosen at random in Central District Council randomly hence the results cannot be generalised. The other reason is that some teachers were not comfortable with video filming.

**Ethical considerations**

According to Opie (2004) in Moalosi (2015) any research that involves people has the potential to cause unintentional damage and has the need for a careful elaboration on how the moral aspect of the envisaged research will be addressed to minimize the damage. Ethics are norms or standards of conduct that distinguish between right and wrong. They help to determine the difference between acceptable and unacceptable behaviours. According to Shamoo and Resnik (2015) argues that there are several reasons why it is important to adhere to ethical norms:

a) Norms promote the aims of research such as knowledge, truth and avoidance of error.eg, prohibitions against fabricating, falsifying, or misrepresenting research data the truth and minimize error.

b) Since research often involves a great deal of cooperation and coordination among many different people in different disciples and institutions, ethical standards promote the values that are essential to collaborative work such as trust, accountability, mutual respect and fairness.

c) Many of the ethical norms help to ensure that researchers can be held accountable to the public, for instance federal policies on research misconduct etc.

d) Ethical norms in research also help to build public support for research.

Ethical codes address issues of honesty, objectivity, respect for intellectual property, social responsibility, confidentiality, on-discrimination and etc. (http://ethics.elsevier.com/index.asp) Some Organisations have Institutional Review Boards (IRB); This is a panellist who makes sure that there is safety in human subjects and that human rights are protected.

The following ethical consideration was done:

**a) Beginning the study**

The researcher informed the participants about the purpose of the study and presented a consent form to the participants. The participants (teachers and students) were told that their participation will be treated as confidential. Participants were further informed that failure to participate in the study will not have any effect on their daily work.

**b) Collecting data**

Data collection is the process of gathering and measuring information on targeted variables in an established systematic fashion, which then enables one to answer relevant questions and evaluate outcomes (http://en.wikipedia.org/wiki/Data_analysis).The data was collected in two stages, pre data collection (before teachers going through a Professional development and post data (after teachers going through a professional development programme).

**Sample**

The data was collected from five (5) schools both mathematics teachers and students. That is two (2) primary schools, two (2) junior secondary schools and one (1) senior secondary school.

**Pre data collection**

I studied the records (lesson plan), observations, interviewing both the students and teachers. I lastly recorded a video of two primary teachers, two Secondary teachers and one (1) Senior secondary School teachers teaching Mathematics. The teachers were taken through a professional development programme, being taught about the topics.

**Post data collection**

I studied the records (lesson plan), observations, interviewing both the students and teachers. I recorded a video of two primary teachers, two Secondary teachers and one Senior secondary school teaching mathematics.

**Data analyzed**

Instead of participants to use their real/original names, fictions or sydonomius was used instead. All the data for pre and post were analyzed together with the records (lesson plans) and interviewing both the students and teachers.

**Researchers role**

According to Creswell (2014:256) in Kunene (2016) urges that researcher's role necessitates the identification of assumptions, values and biases, as the primary data collection instrument at the outset of the study. The researcher compared watched the video taking points as to which teacher didn't apply the method of legitimation.

**Conclusions and Recommendations**

It was found that the post lesson plan was different from the pre lesson plan. From the video, it was observed that teachers applied the concept of legitimation and during the interviews both the students and teachers said they understood the lesson very well. It is recommended that teachers need opportunities to relearn the mathematics they teach in schools such as attending short courses during school vacations. According to Moalosi (2014) also found that professional development is important mathematics teaching and learning. There is a need for research that looks into the relationship between teachers appeals and learners to explore the extent to which learners learn what was taught in class.

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**Article 14**

# An assessment of the application of ASEI/PDSI principles in Biology in Taita Taveta county, Kenya

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**Abstract**

Despite the teachers of Biology being trained on ASEI/PDSI principles, the national examination performance in Biology continues to be dismal. This study sought to find how effectively teachers have applied ASEI/PDSI methodologies in teaching Biology. The study objectives were: first, to find out how the SMASE INSET influenced the implementation of ASEI PDSI principles, and second to assess the application of ASEI/PDSI principles that were dominant in teaching Biology. The study employed the survey design, and the target population was all the 48 secondary schools in Taita Taveta County. The researchers selected 16 secondary schools through stratified and simple random sampling techniques. Data was collected through the use of questionnaires and class observations. The reliability of the research instruments was ascertained through the test re-test method. The use of experts did the validity of the instruments. The collected data was analyzed quantitatively. The study findings showed that most Biology teachers had attended the SMASE INSET. The training environment was weak, and teachers lacked enough teaching resources and enough time to apply the ASEI/PDSI principles. The study further found that the lecture method dominated the teaching of Biology. The study concluded that teachers had a low opinion towards the effectiveness of the INSET and that constraints were hindering the application of ASEI and PDSI principles. The study recommends the need to address misconceptions of teachers towards the INSET and the barriers to the application of the ASEI/PDSI principles for better performance in Biology.

**Keywords:** *ASEI/PDSI principles, Biology, INSET*

**List of abbreviations and acronyms:** *ASEI - Activity, Student-centered, Experimentation, and Improvisation, CEMASTEA - Centre for Mathematics and Science and Technology Education in Africa, COMTEC-Communication and Technology (department in Kenyatta University),H.O.D. - Head of Department, INSET- In-service Training, KNEC- Kenya National Examination Council, KCSE- Kenya Certificate of Secondary Education, PDSI -Plan Do See and Improve, M.O.E. - Ministry of Education, NACOSTI – National Council of Science and Technology, SMASE- Strengthening Mathematics and Science Education*

## Introduction

## Background to the Study

Biology is a branch of science that deals with the study of living things. It involves the interdependence of living beings and their relations to the physical world. Biology is essential as it gives skills, knowledge, and attitudes in the promotion of good health, an increase in food production and poverty reduction. Besides, Biology is core to entry into crucial careers for scientific innovations required to better lives, for example, genetic engineering, medicine, agriculture, among others (Owiti, 2009). Given the vital role Biology plays in everyday living, the government of Kenya through the Strengthening Mathematics and Science Education (SMASE) program, has put much effort to aid in the acquisition of Biology skills, knowledge and attitudes among other Science and Mathematics subjects. This study sought to provide evidence-based research on whether the recommended ASEI and PDSI principles by the SMASE INSET are applied in the attainment of improved learning outcomes, as illustrated by the national examinations.

SMASE, a project by the government of Kenya in conjunction with Japan, aims to guide teachers in curriculum interpretation and implementation (SMASE, 2000), amongst other objectives. After piloting, the SMASE program went through four cycles. The first cycle was to address teachers' and students' attitudes to sciences and mathematics; the second cycle was to introduce the opportunities for 'doing' rather than being 'told.' This phase involved the ASEI (Activity, Student-Centered, Experiment, and Improvisation) and PDSI (Plan, Do, See, and Improve) strategies. The third cycle was to implement ASEI and PDSI strategies, whereas the fourth cycle was to entail the enhancing and sustaining of ASEI and PDSI principles. Liburu (2011) shows that the four cycles of training were put in place as planned from the year 2004 to 2007. Liburu (2011) further reveals that as much as SMASE training had an intended positive impact on the teaching and learning of sciences, the principles taught were poorly implemented. Since then, the government of Kenya established a Centre for Mathematics and Science and Technology Education in Africa (CEMASTEA), which has continued to provide and coordinate In-Service Education and Training (INSET) for practicing teachers of Mathematics and Science amongst Biology.

Frechtling (2000) recommends the need for classroom research in understanding teaching and learning of Biology. There is a need to get into classrooms, watch what the teachers do, and ask them to defend their choices. Research shall enable us to find out the reasons why there are a gap and ways of lessening this gap between the curriculum's intention and its reality on the ground. Further, (William et al. 2007; Tarmo, 2016) assert that classroom research that explores teachers' actual classroom practices and their beliefs and knowledge results in more targeted professional development. Thus, to find ways to support effective teaching and learning of Biology, there is a need to make careful descriptions of the status of the implementation of Biology from where curriculum policymakers and implementers can base their improvements.

There is a need to find out why, despite the teacher's participation in SMASE INSET training, there has been no significant improvement in the performance of Biology. In the last few years, Biology has been the worst performed subject in the Kenya Certificate Secondary Education (KCSE). In particular, Taita Taveta County, Kenya, has continually performed poorly in KCSE Examinations. The County has been scoring a low grade of less than 3.00 in Biology in the last six years (KNEC, 2018). The study, therefore, investigated the application of ASEI and PDSI principles in instructional strategies of Biology to improve the teaching and learning of Biology and consequently improve the performance of Biology in national examinations.

**The study problem**

The Kenya government introduced the SMASE INSET program in an attempt to improve the teaching of Mathematics and Sciences amongst Biology. However, despite the fact that the program has been running for more than a decade, the performance in Biology remains poor. The poor performance suggests that the application of the teachings of the SMASE INSET may be facing challenges. The current study sought to find out the application of ASEI/PDSI principles in the teaching and learning of Biology in Taita Taveta County, Kenya.

**Objectives of the Study**

The study aimed to:

a) Assess the effectiveness of SMASE INSET in preparing teachers to apply ASEI/PDSI principles in teaching Biology in Taita Taveta County.

b) Assess the extent of teachers' application of ASEI/PDSI principles in teaching Biology in Taita Taveta County.

**Significance of the Study**

This study is vital to the government in informing the current situation of teaching and learning of Biology. The study is also crucial in providing suggestions for enhancing better teaching and learning of Biology. Also, the study is essential to classroom teachers in enhancing the practical application of ASE/PDSI principles in Biology. Besides, the study can form a basis for further research.

**Limitations of the Study**

The study was limited due to the vastness of the area to be covered and lack of funding. The study was limited to the School Principals, Biology teachers, and forms three Biology students in Taita Taveta County.

**Literature review**

**The Effectiveness of INSET on Implementation of ASEI PDSI Principles**

Loughran (2006) defines teacher education as life-long learning, starting before one enters the teaching career (pre-service) and continuous throughout one’s career (in-service). Thus student teachers develop knowledge and skills of teaching and learn how to apply them in practice competently. Research by Sugail and Honer (2002), cited in Olitsky (2013), underscores the importance of encouraging feedback as much as instructional or corrective feedback. Teachers, therefore, require frequent job-embedded support and high-quality feedback as well as constant in-service training.

In- service, teacher education covers those activities directed towards remediation of perceived lack of skill of understanding (Namunga and Otunga, 2012; Boudry & Pigliucci, 2018). In-service education, therefore, should be an ongoing process that promotes professional and personal growth of teachers. Dori and Herscovit, (2005) asserted that effective in-service education and staff development programs address local school needs, in-service and staff development participants are actively involved, in-service teacher programs should be school-based where teachers get mentored and learning relationships between individuals who work together in a similar organization developed.

Van Dier, Beijaard and Veloop, (2001) note that a national in-service project pressures schools to respond to centralized demands, puts the burden of funding on principals' shoulders, and hinders staff development in individual schools. In support of this view, Namunga and Otunga, (2012) state that though teacher participation in national in-service programs is high, the content tends to concentrate on theoretical or subject matter rather than on school practice and development. As a result, although facilitating in-service programs could be expensive, teachers may not be benefiting from them since the needs of each school are different.

**ASEI/PDSI principles in instructional strategies**

Teachers have a significant role in determining, interpreting, and implementing the curriculum. A study by Hativa (2002) illustrates that teachers' instructional strategies align with the teachers' general beliefs. The study used a combination of student and teacher interviews, student and teacher questionnaires, and direct observations of teaching. Two teachers who demonstrably exhibited inferior teaching effectiveness were chosen for the study. More information on problem teaching behaviours was identified, which included things like presenting no framework overviews at the start of a lesson, or summaries at the end of a lesson. The information showed no transition signals during lessons, skipping steps in logical progressions, and presenting material at too abstract a level with minimal examples. The study showed that; lessons crowded with detailed information seemed to align with a belief in the necessity of 'covering the syllabus,' and teacher-only presentations seemed to align with a belief in strict lecturing as the only feasible method for teaching large classes. Therefore, students continue to listen, copy notes, and watch demonstrations of experiments in science classes while their teacher's lecture. This study shows the helplessness of teachers to move towards learner-centered methodologies due to their beliefs.

The innovations introduced in most instructional programs include strategies for promoting the construction of knowledge on the part of the learners, using various resources such as movies, about model teachers, videoed lessons given by excellent teachers, class interactions, and learning activities. However, Tarmo (2016) notes that laying strategies for learner-centered teaching is not enough without addressing the teacher's misconceptions about facilitating student-centered learning. Otherwise, the efforts towards learner-centered methods remain futile.

## Research methodology and design

### Research design

The study used survey design. The researchers collected data through the use of questionnaires and class observation guides.

### Research location

The study locale was Taita Taveta County, Kenya, which has continually performed poorly in KCSE Examinations. All the sub-counties in Taita Taveta County have been scoring a low mean grade of less than 3.00 (which is a 'D') in Biology for the last six years (KNEC, 2018).

### Target population

The study targeted all secondary schools in Taita Taveta County, which has a total of 48 secondary schools with an enrolment of 900 forms, three Biology students. The study targeted all the 48 principals, 96 Biology teachers, and 900 forms three Biology students. The study thus targeted a total of 1044 respondents. For teaching and learning, there is an interaction between students, teachers, and administration represented herein by the principals.

### Sampling procedures and sample size

The study employed stratified random sampling to ensure that each subgroup was represented. The subgroups included: Mixed schools, Boy schools, and Girl schools. The researchers sampled thirty-three percent of schools in each subgroup. The sample, therefore, agreed with Cohen and Manion, (1994) that in a survey study, one-third of the accessible population is a representative sample. Since the target population was the Principals, Biology teachers, and form three Biology students, 16 Principals, 32 Biology teachers, and 300 students got sampled out. Thus, the total sample population was 348, as shown in Table 3.1:

**Table 3.1 Sample Size**

| Respondent category | Mixed schools | | Boy schools | | Girl schools | | Total Number | |
|---|---|---|---|---|---|---|---|---|
| | Target | Sample | Target | Sample | Target | Sample | Target | Sample |
| Principals | 30 | 10 | 10 | 3 | 8 | 3 | **48** | **16** |
| Teachers | 60 | 20 | 20 | 7 | 16 | 5 | **96** | **32** |
| Students | 480 | 160 | 240 | 80 | 180 | 60 | **900** | **300** |
| TOTAL | **570** | **190** | **270** | **90** | **204** | **68** | **1044** | **348** |

## Research instruments

The study used questionnaires, and class observation guides to collect data. The respondents to the questionnaires included Principals, Biology teachers, and form three Biology students, respectively. Questionnaires were used in this study because, according to Gay, (1992), they are appropriate for gathering massive amounts of data from many respondents inexpensively and in good time. Class observation guides, on the other hand, were used by the researcher to observe Biology lessons.

## Piloting of research instruments

Before carrying out the pilot, respondents in the pilot schools were made aware of the intended study. Researchers Piloted instruments in two purposefully selected schools. Piloting, according to Mugenda and Mugenda (1999), enables the researcher to check on validity, reliability, consistency, and comprehensibility of research instruments.

## Validity of research instruments

The instruments were exposed to open scrutiny by a team of Biology experts in the Communication Technology (COMTEC) department, Kenyatta University. Through scholarly criticism, polished instruments were obtained. This was in agreement with Creswell, (2014), who recommends that research instruments can be validated through the application of content validity analysis by expert judgment.

## Reliability of research instruments

Questionnaires and the class observation guides were tested and re-tested in the pilot schools to ensure reliability. The consistency of the responses indicated that the instruments were reliable. Orodho, (2011)indicates that test and re-test of instruments can be used to determine the reliability of instruments.

## Data collection procedures

Before embarking on the collection of data, the researchers applied for authority from the National Council of Science and Technology (NACOSTI) to conduct the research. Once permission was granted, the researchers surveyed the region. This preceded a formal call at the County Director of Education and the Sub County Education Officers to brief them about the intended research.

The researchers delivered the questionnaires to the principals in person in envelopes with which to seal the completed questionnaires to ensure confidentiality.  This was done when schools were in session for easy accessibility and availability of the respondents. Delivery of questionnaires in person enabled the researchers to clarify issues and get feedback immediately. Ample time was given for the questionnaires to be filled. The Biology teachers and the students filled the questionnaires and gave them to the principal, where the researchers collected them in person. Personal collection ensured a high response rate of at least (90%) of the respondents.

Next, the researchers arranged with the Biology Head of Department (H.O.D.) when at least one form three Biology lessons could be observed in each of the 16 sampled schools. This was followed up firmly based on the given dates and observation of the classes done using class observation guides. The researchers made notes during the observation, which were used in the analysis of data.

**Data analysis plan**

For closed-ended responses, numbers or symbols were assigned using a codebook to simplify the data for analysis. The data was then entered in Statistical Package of Social Science) SPSS) for analysis. Descriptive statistics were used to analyze quantitative data, which included frequency distribution tables and percentages. These were obtained concerning each objective of the study. The data were summarized and then presented with the aid of tables and charts. The mode of presentations of the findings was by objectives. This agreed with Satyanarayan, Bode, and Henry. (1983) who recommend analysis by objectives in descriptive statistics.

**Data analysis, results and discussion**

**Effectiveness of SMASE INSET on preparing teachers to apply ASEI PDSI principles**

The first objective was to find out the effectiveness of SMASE INSET on preparing teachers to apply ASEI/PDSI principles. First, the study established the extent to which Biology teachers attended and the extent they found the SMASE INSET helpful. The biology teachers' responses are as in table 4.1

**Table 4.1 Responses by Biology teachers on attendance and helpfulness of the SMASE INSET**

| Response | Frequency | Total Popn (N) | Percentage % |
|---|---|---|---|
| Have attended SMASE INSET | 26 | 32 | 81 |
| Attended, but the training not helpful | 9 | 15 | 60 |
| Attended, but do not implement the INSET teachings | 9 | 15 | 60 |

Table 4.1 shows that 81% of the Biology teachers attended the SMASE INSET. It was, however, found out that 60% of the teachers who attended the INSET did not find the SMASE training helpful in their teaching. This finding was as reflected in their responses, whereby 60% further indicated that they did not implement the INSET teachings. The fact that most teachers did not find the INSET helpful was contrary to Namunga and Otunga (2012), who advocate for in-service education as it is necessary and appropriate for correction of deficits in teachers' skills.

The study sought to find out why most Biology teachers indicated that the SMASE INSET was not helpful. Responses by principals on issues raised by Biology teachers concerning SMASE program are as shown in table 4.2

**Table 4.2 Responses by principals on issues concerning SMASE INSET**

| Issue | Frequency | Percent % |
|---|---|---|
| No motivation to trainers and trainees, reimbursement of transport, and remuneration for trainers delayed for months. | 3.0 | 20.0 |
| A poor environment of training, in most INSETS teachers, use classrooms for venues and students' chairs with no writing surfaces (table). Some training venues are not big enough or well ventilated. Other government workers of the same job groups do their training in big hotels with excellent facilities. Why not teachers? | 7.0 | 40.0 |
| Do not attend | 3.0 | 20.0 |
| No time to implement the ASEI/PDSI principles, Abstract and unrealistic | 3.0 | 20.0 |
| Total | 16.0 | 100.0 |

Table 4.2 shows that 40% of the principals mentioned poor training environments as a significant issue against the SMASE INSET. Teachers complained that the venues for the INSET were students' classrooms, and the furniture was students' chairs with no writing surfaces such as tables. Some training venues were not big enough or well ventilated. Teachers argued that other government workers of equivalent job groups attended their in-service training in big hotels with excellent facilities. Teachers were demotivated and mentioned that the government discriminates against them as compared to other government workers. Teachers' and trainers' motivation to attend the INSET was another challenge mentioned by the principals (20%). The teachers mentioned that reimbursement of transport expenses and remuneration for trainers delayed for months. Even for the many who attended the INSET, teachers lacked time to apply the ASEI/PDSI principles, which required more time against covering the vast syllabus. Besides, 20% of the principals reported that teachers found the SMASE principles abstract and unrealistic to some topics in Biology.

These findings suggest that the INSET was lacking in terms of addressing the institutional and teachers' needs. Dori and Herscovitz (2005) suggest that for effective in-service education and staff development, programs should be directed towards local school needs, participants should actively be involved and that effective programs should meet participant needs. Some of the complaints such as lack of motivation concurred with researchers Anderson and Helms, (2001): Boudry & Pigliucci, (2018) who mention that there is difficulty in proposing in-service training to teachers who have insufficient motivation. Complaints such as inadequate training environment point out to insufficient funding. The finding was in agreement with Van Dier, Beijaard and Veloop, (2001), who states that a national in-service project pressures schools to respond to centralized demands, puts the burden of funding on principals' shoulders and hinders staff development in individual schools.

**Implementation of ASEI and PDSI principles in instructional strategies**

The second objective was to identify the principles of ASEI and PDSI principles in instructional strategies of Biology in Taita Taveta County. SMASE (2000) recommends ASEI (Activity, Student-Centered, Experiment, and Improvisation) and PDSI (Plan, Do, See and Improve) strategies for effective teaching and learning of sciences, including Biology. The study, therefore, sought the extent to which teachers applied these principles in their instructional strategies. Responses by teachers showing activities dominant in their instructional strategies in the implementation of Biology are as in table 4.3

**Table 4.3 Responses by Biology teachers on activities dominant in their Biology instruction**

| **Statement** | **S.A. (%)** | **A(%)** | **S/A (%)** | **D (%)** | **S.D. (%)** |
|---|---|---|---|---|---|
| Teachers design Biology experiments and give procedures for students to follow. | 50.0 | 12.5 | 12.5 | 12.5 | 12.5 |
| Students read and follow experiment procedures from a textbook. | 12.5 | 12.5 | 12.5 | 50.0 | 12.5 |
| Students design and carry out experiments using apparatus provided | 12.5 | 12.5 | 12.5 | 25.0 | 37.5 |
| Project work is useful and is carried out each term. | 38.0 | 8.0 | 8.0 | 8.0 | 38.0 |
| Students work in groups in project work and make written reports of the project. | 37.5 | 12.5 | 12.5 | 12.5 | 25.0 |
| Group work and cooperative learning are often used in Biology classes. | 12.5 | 12.5 | 12.5 | 12.5 | 50.0 |

| | | | | | |
|---|---|---|---|---|---|
| During Biology lessons, teachers' questions demand knowledge from other subjects. | 12.5 | 12.5 | 12.5 | 50.0 | 12.5 |
| Well prepared lectures are efficient and effective for most Biology topics. | 50.0 | 12.5 | 12.5 | 12.5 | 12.5 |
| The laboratory is the center for Biology instruction. | 37.5 | 12.5 | 12.5 | 12.5 | 25.0 |
| Biology facts and definitions should provide the core of Biology courses. | 50.0 | 12.5 | 12.5 | 12.5 | 12.5 |
| The laboratory should be used to report and verify experiments that students have read. | 50.0 | 12.5 | 12.5 | 12.5 | 12.5 |
| Laboratory investigations should be used to introduce more science topics. | 37.5 | 12.5 | 12.5 | 12.5 | 25.0 |
| Biology teachers should have in mind specific answers to questions they pose in class. | 37.5 | 12.5 | 12.5 | 12.5 | 25.0 |
| Some time in Biology course should be used for examining the original work of scientists in the original formation. | 12.5 | 25.0 | 12.5 | 12.5 | 37.5 |

**Key: S**.A.- Strongly agree, **A**- Agree, **S/A**-Somewhat agree, **D**- Disagree, **SD**- Strongly disagree

Table 4.3 shows that fifty-two and a half percent of the Biology teachers disagreed that students read and follow procedures from Biology textbooks. Nevertheless, a majority of 62.5% of the teachers disagreed that students design and carry out their Biology experiments. However, most teachers (52.5%) agreed that teachers design experiments and give procedures for students to follow. The above responses were in agreement with Smerdon and Bukam (1999), and Faikhmata, (2018)’s different studies, which showed an attempt to move towards learner-centered strategies but hampered with many constraints, which forced teachers to use the lecture method instead most of the times.

Table 4.3 further shows that 50% of the teachers agreed that project work was useful though none of the schools had a project ongoing. On the other hand, 62.5% of the teachers disagreed that group work activities and cooperative learning were often used in Biology classes. The same majority of 62.5% agreed that the lecture method was efficient and effective for most Biology topics. These responses concurred with Boudry & Pigliucci (2018), which indicated that teachers viewed the lecture method as the most expeditious method for covering the vast syllabus.

Sixty-two and a half percent of the teachers agreed that Biology facts and definitions are the core for Biology lessons. Only 12.5% of the teachers disagreed with this statement. The same pattern of agreement responses occurred when teachers were asked if they should have specific answers to questions in class. However, a reverse response pattern occurred when asked if questions asked during Biology lessons demand knowledge from other subjects. These responses again favored teacher-centered methods hence the need to embrace Tamar, (2016)’s advice that: teachers' misconceptions must be changed to that of facilitating student learning before student-centered strategies can be adopted very applicably.

Table 4.3 further shows that 50% of the teachers agreed that the Biology laboratory is the center of Biology instruction. They also agreed that laboratory investigations introduce most science topics. A majority of the teachers (62.5%) agreed that the laboratory should be used to repeat and verify experiments students have read. These findings show that there was an attempt by teachers to support ASEI PDSI principles (SMASE, 2000; Faikhmata, 2018). These responses yet again showed the helplessness of teachers to move towards learner-centered methodologies much as they believed in them.

The study sought to understand the main challenges the teachers faced in attempting to implement the ASEI/PDSI principles. Figure 4.1 shows the responses by principals on the challenges teachers reported they faced in implementing the ASEI/PDSI principles.

**Figure 4.1 Principals' responses on challenges faced by Biology teachers in implementing ASEI/PDSI principles**

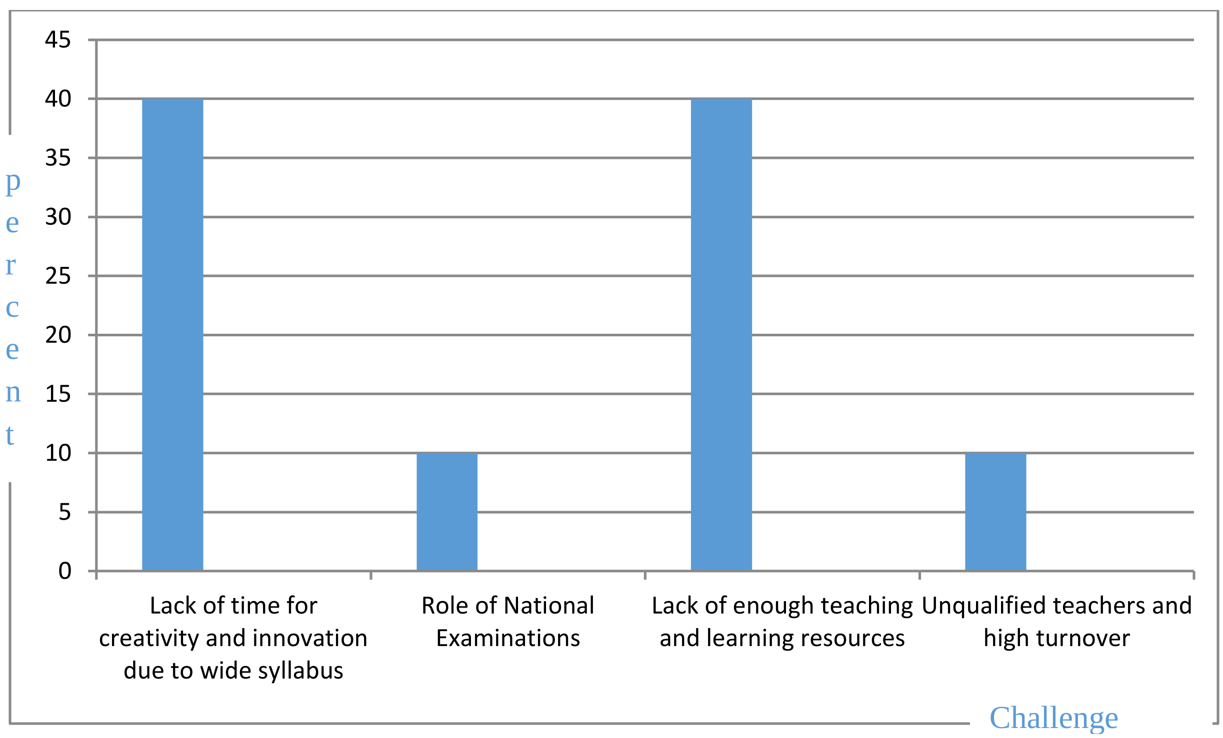


Figure 4.1 shows that 40% of the principals pointed out that Biology teachers could not effectively implement the ASEI/PDSI principles for lack of time for creativity and innovation due to the vast syllabus. Teachers lacked time to exercise methods of teaching, such as projects, group work, and laboratory work, because such methodologies that apply ASEI/PDSI principles were time-consuming. Figure 4.1 further shows that 40% of the principals indicated that Biology teachers

could not effectively implement the ASEI/PDSI principles due to a lack of teaching and learning resources. Lack of I.C.T., films slides which could facilitate easy learning using ASEI/PDSI principles were unavailable, forcing the teachers to use the few available textbooks which encourage lecture and other traditional methods instead. Finally, a small proportion of principals noted that Biology teachers were not able to effectively implement ASEI PDSI due to the role of national examinations (10%) and lack of qualification and high turnover (10%).

The above findings agreed with Roehrig, Kruse, and Kern (2005), who indicate that much as recent activities may well promote academic proficiency, teachers complain about several constraints hampering them in carrying desirable curriculum tasks. Some of those barriers as stated by Cronin Jones, (1991) cited in Ferral and Hattice (2009) include the need for additional resources, need for extra adult help in classrooms, behavior problem with students and covering full content which must be learned and reproduced for examinations which are used as an accountability mechanism.

## Conclusions and recommendations

### Conclusions

The study arrived at the following conclusions:

a) The implementation of SMASE INSET had challenges that affected its effectiveness in preparing Biology teachers to apply ASEI/PDSI principles in the classroom. This resulted in a significant number of Biology teachers having low opinions towards the SMASE INSET.
b) Even though Biology teachers were willing to apply the ASEI/PDSI principles, they faced several constraints that made them use the traditional lecture method, which they found efficient in covering most significant content in Biology. Biology teachers thus applied ASEI/PDSI principles to a small extent.

### Recommendations

The study, therefore, recommends that:

a) The SMASE INSET should address the unique needs of the Biology teacher's experience at the school level to enhance the application of the ASEI PDSI principles.
b) The SMASE INSET should address teachers' misconceptions and attitudes in addition to the emphasis of ASEI/PDSI methods.
c) The government should address barriers against the application of the ASEI/PDSI methods such as inadequate training environment, lack of I.C.T. and other learning resources, emphasis in examinations, and vast syllabus against time.

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**Article 15**

# Visualization processes in conceptual teaching of word problems in grade 9 mathematics classes

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**Abstract**

This study underpinned by the social constructivist perspective, focused on visual processes for enhancing Teacher Professional Development in South Africa. We surveyed eighty-seven mathematics teachers from one district in the Northern Cape Province of South Africa focusing on their experiences, elating to how and to what extent they use visual approaches to teach Pythagoras' theorem word problems. Three teachers purposively selected took part in the intervention programme. Teachers' ability to build on prior knowledge rooted in everyday life, use of multiple representations and making connections among ideas in mathematics and real life emerged from the survey and interviews. Lack of resources in schools, time constrains and some syllabi related issue were noted as reasons why few teachers were using visualization strategies to make connections during teaching. We conclude that there is need for in-service programs and workshops to support teachers on how to optimally use visual tools and strategies in mathematics classes.

**Key words:** Problem-solving, visualisation, word-problems, conceptual understanding

## Introduction

In mathematics curriculum, a number of reasons necessitates the inclusion of word problems. In South Africa, the Department of Basic Education (DBE) (2011) posits that mathematical problem solving (MPS) enables us to understand the world around us, and teaches us to think creatively. While problem solving especially in mathematics has many benefits, literature reveals that learners express difficulties in problem solving (Fatmanissa & Kusnandi, 2017). Research has since shown that visualization processes aid understanding, reasoning and deeper conceptual understanding of mathematical concepts (Kanyalioglu, Kanyalioglu & Isik, 2008) in educational settings. Visualisation processes in mathematics pedagogy refers to the deliberate use of visuals to promote deep understanding of concepts "both from teachers introducing mathematical ideas visually, and students using visuals to think and make sense of mathematics and connecting previously unconnected theories in mathematics," (Boaler, Chen, Williams, & Cordero, 2017, p. 5, 7) and mathematics teaching and learning. We thus in this paper are driven by a strong conviction that one key way of strengthening mathematics and science education in Africa is through deliberate incorporation of visualization processes in teaching and learning.

Having taught high school mathematics for many years now, we have observed that learners struggle with MPS across secondary school grades. This is due to a couple of reasons, one of which is learners' insufficient opportunities to engage in the exploration of word problems. In South Africa, the Annual National Assessment (ANA) diagnostic report of 2014 noted that use of ineffective teaching methods was one of the key causes of the challenges experienced by learners in certain mathematics topics that include mathematics word problems (MWPs) (DBE, 2014). This study thus argues that there is an urgent need to explore the pedagogical approaches used by teachers in the teaching of MWPs in this case. We hence submit that there is need to research effective pedagogies that can enhance mathematics teaching in the South African classroom and in turn, the other parts of the continent. Visualisation processes are considered herewith as some of the approaches that can enhance conceptual understanding in problem solving. This study thus focused on understanding the teaching of word problems on Pythagoras' theorem using visual approaches and was guided by the following questions: *How do grade 9 mathematics teachers in a selected district teach problem solving on the Pythagoras theorem prior to an intervention program? What are the selected teachers' perceptions and experiences in using visual models to conceptually teach word problems on Pythagoras theorem as a result of participating in an intervention program?*

## Conceptual framework

In this study, three main constructs- Mathematics word problems, visualization processes and conceptual understanding are key and hence are presented and discussed in the next section.

## Mathematics Word Problems (MWPs)

In many curricula including that of South Africa and other African countries, school mathematics is substantially word problems taught at all levels of school education. The definition of MWPs is not always clear-cut. In this study, we will consider MWPs to refer to any mathematical exercise where significant background information on the problem is presented as text rather than in mathematical notation (Jupri & Drijver, 2016). Two key aspects are involved in MWPs these are mathematics and language. Therefore, in dealing with word problems, ''teachers need to understand them not only as a part of mathematical test or task, but also as a language object that should be addressed from perspectives other than simply mathematical operations'' (Fatmanissa & Kusnandi, 2017, p. 88). Since language plays an imperative role in understanding word problems in mathematics (Yonson, 2017), the mathematical language involved in MWP must be understood in order for one to successfully solve a given problem (Fatmanissa & Kusnandi, 2017). Literature, however, reveals that certain groups of learners (English language learners (ELLs), learners with low and average mathematics levels, among others) fall behind when language is involved in MWPs (Abedi & Lord, 2001).

In Africa, majority of learners are taught mathematics in a language not their first. The effects of such a phenomenon has since been researched extensively in and outside Africa (Abad, 2010; Adler, 2001; Antony & Walshaw, 2009; Moschkovich, 2002) and such learners learning in the language not their first needs extra attention as compared to their counterparts using their first language. Thus, for enhancing conceptual understanding in ELLs classes, Abedi and Lord (2001) emphasise the need for modifying language demands in MWPs. Research therefore, attributes learners' challenges in handling MWPs to the deleterious effects of the linguistic processing required in solving these problems. This study thus advances the use of visualization processes as one way to mitigate such language related challenges during problem solving.

Several studies (Fatmanissa & Kusnandi, 2017; Van Garderen & Montague, 2003; Yonson, 2017) reported that poor performance in MWPs suggests that mathematical skills do not appear to be the issue but other contributing factors that mainly including text comprehension problems, highlighting difficulties predominately caused by linguistic aspects. Jupri and Drijvers' (2016) research support these findings where they attribute students' difficulties in handling MWPs to the mathematization perspective, which they categorized into horizontal and vertical mathematization. They define mathematization as the activity of transforming a realistic problem into a mathematical problem (that is, horizontal mathematization), as well as solving the problem expressed in a model and interpreting the solution (that is, vertical mathematization). In this study, we adopted Konyalioglu et al.'s (2012) argument that the use of visualization processes in MPS has potential to support learners' comprehension and coming up with multiple solution opportunities during the mathematization process.

**Visualization in mathematics**

In defining visualisation, Presmeg (2006) posits that it is ''the process of constructing and transforming both visual mental imagery and all the inscriptions of spatial nature that maybe implicated in doing mathematics'' (p. 206). In a more detailed way, Arcavi (2003) defines visualization as the ability, the process and the product of creation, interpretation, use of and reflection upon pictures, images, diagrams, in our minds, on paper or with technological tools, with the purpose of depicting and communicating information, thinking about and developing previously unknown ideas and advancing understandings (p. 217).

Arcavi's definition emphasizes that visualization can be a powerful tool in mathematics teaching and learning as it gives meaning to mathematical concepts and the relationship between them. Both external and internal visualization processes are crucial in the teaching of MWPs in order to enhance learners' conceptual understanding. De Koning and van der Schoot (2013) define external visualization as nonverbal physical representations of a concept or text content constructed either by a learner or by a teacher. Internal visualization is the ability, the process of creating, interpreting, using and reflecting upon pictures, images, diagrams in our minds (Arcavi, 2003; Presmeg, 2006), and is an effective approach for honing comprehension (De Koning & van der Schoot, 2013). According to Pape and Tchoshanov (2001), the development of a learner's representational thinking is a two-sided process that entails an interaction of internalization of external representations and externalization of mental images. However, De Koning and van der Schoot (2013) argue that it is crucial to keep in mind that the final goal of instructing learners how to visualize text situations is to aid them towards the automatic construction of internal representations of events described in the text.

Various visual models for teaching mathematical concepts such the Pythagoras' theorem are found in literature (Burk, 1996; Roscoe, 2014) including the volume models, the water models, the beads models, the area models and the scaled-up versions of right-angled triangles. In this study, we only consider two **area models** that uses areas of squares to establish a relationship between the lengths of the sides in each respective right triangle. In the other model, the same proof is presented in a manipulative puzzle to be put together. The square drawn on the bigger leg is cut into four pieces and teachers then need to show how the square drawn on other leg and the four pieces from the cut square could be arranged to cover the square on the hypotenuse.

The third model, the scaled-up versions of a right-triangle approach, entails scaling a right triangle with sides ***a, b*** and ***c*** three times (Burk, 1996). That is, one triangle is scaled by length ***a***, another by length ***b***, and the third one by length ***c***. The three scaled up versions of the original triangle put together create new shapes whose properties and congruency criterions are used to make sense of Pythagoras' theorem. Such models are crucial and necessary for visually and conceptually aiding the teaching of Pythagoras' theorem and applying it to solve word problems in this case.

## Conceptual understanding in mathematics teaching

As noted by Kilpatrick, Swafford and Findel (2001), conceptual understanding is an integrated and functional grasp of mathematical ideas. Kilpatrick et al., (2001) further stress that learners with conceptual understanding know more than isolated facts but are able to learn by connecting new ideas to what they already know. Thus, teachers should endeavor to promote such in mathematics teaching. With conceptual understanding, there is promotion of connection making resulting in learners gaining confidence, which acts as a stepping-stone for them to move to another level of understanding (Kilpatrick et al., 2001).

Kilpatrick et al. (2001) presents four key conceptual understanding indicators necessary for this study. These are first, ***building on prior knowledge*** referring to the teacher's ability to make links between the mathematics he is teaching and what learners already know. Secondly, is ***representing mathematical concepts in different ways,*** which refers to the teachers' ability to represent the same mathematical concepts, presented in a particular word problem in diverse ways and exploring the relationships with the learners. Third is ***connecting concepts and ideas in mathematics*** where the teachers' ability to discuss the similarities and differences of the various representations and exploring and connecting these ideas to other mathematical domains is crucial. Lastly, is ***extending mathematical concepts to real- life contexts***. This concept requires the teachers to relate what they are teaching to new areas or daily life contexts thereby enabling learners to see the practical applications of this knowledge outside the classroom. In this study, the conceptual understanding pointers discussed here form an integral part of our analytical framework.

### Theoretical framework: Social constructivism

This study was informed by Vygotsky (1962)' social constructivist perspective that aimed at epistemologically empowering mathematics teachers as social agents during workshops after which they had to implement their learning. In a social constructivist perspective, the process of knowing has at its roots social interaction (Von Glasersfeld, 1995) seen by Vygotsky (1962) as an integral part of learning. That is, learning always originates in some form of social participation that becomes internalized to change our mental functioning. Similarly, Ernest (2010) argues that learning and knowledge construction take place in the social arena, in the 'space between people', even if its end products are appropriated and internalized by those persons individually (p. 40).

Based on Vygotsky's work, Ernest (2010) argues that social constructivism regards learners and the realm of the social as indissolubly interconnected emphasizing that it is through social interaction mediated by tools that human learning is born. Vygotsky (1962) further assert that language usage in the classroom is the most important tool for social mediation; it can be used as a tool to mediate social interaction and collaboration, and for learners to express their learnt knowledge. Yonson (2017) also asserts that language plays a vital role in the understanding of word problems in mathematics. In this study, language and visual teaching approaches were the tools used to support learners in their meaning making processes.

### Research methodology

This study, which followed an interventionist approach in a district in one of the provinces in South Africa, explored three models to teach Pythagoras' theorem word problems. These were: **two area models** and **scaled-up versions of a right triangle.** Mixed methods approach was used in this study. Data were collected through survey questionnaire, lesson observations and stimulated recall interviews.

A survey questionnaire was administered to establish how and to what extent teachers were using visual approaches when teaching Pythagoras' theorem word problems. Eighty-seven teachers responded to this questionnaire. The teachers' questionnaires were coded for identification purposes. For example, **Tr27** refer to teacher number 27 out of the 87. An intervention program that involved three workshops with teachers in the district followed the survey. The intervention focused on how to use visual models to solve MWPs on Pythagoras' theorem followed and on creating an awareness of promoting conceptual understanding in the teaching of mathematics through visualization processes.

After the workshops, three teachers identified in this study as **TA, TB** and **TC** were purposively selected and were observed presenting their lessons on Pythagoras' theorem to grade 9 classes using the three visual models. Teaching was organized in three cycles with each cycle related to one of the models. Lesson observations were video-recorded one lesson per cycle in each teacher's class. One-on-one stimulated recall interview (after each cycle) was conducted with the teacher to establish the participant's views and experiences on how and whether the use of visual models enhanced the teaching of Pythagoras' theorem. At the end of all the cycles, a focus group interview was conducted with all the three teachers and were audio-recorded.

## Analysis of data

First, data from survey questionnaires were analyzed quantitatively using descriptive statistics. Secondly, data were qualitatively analyzed using the analytical tool developed from Kilpatrick et-al.'s (2001) indicators of conceptual understanding to ascertain how teachers in the district teach Pythagoras' theorem and problem solving prior to the intervention.

The recorded videos of lesson observations and interviews were analyzed descriptively using first the same analytical tool developed from Kilpatrick's work. Secondly, a thematic analysis approach, that is, a method of identifying, analyzing and reporting patterns within data, was used. The purpose of this analysis was twofold, first, was to identify and understand how the selected teachers made use of various visual resources provided in the intervention to develop conceptual understanding during their teaching of word problems on Pythagoras' theorem. Secondly, our focus was to identify these same teachers' experiences and perceptions on their use of visual models to teach word problems related to Pythagoras' theorem.

## Findings: Presentation and discussion

The findings are presented and analyzed in two parts: background information and emerging themes.

### Background information

#### *Teacher Qualifications and Experience*

**Table 1: Qualifications of participants**

| **Teacher Qualifications** | Certificate/ Diploma | Undergraduate | PGCE | Honors Degree | Master's Degree |
|---|---|---|---|---|---|
| **Frequency %** | 53 | 4 | 6 | 30 | 1 |

In this study, all teachers who participated were qualified to teach the levels at which they were teaching. We noted that 47% of the surveyed teachers had at least a degree related to mathematics (see Table 1). However, the majority of teachers (53%) were either diploma or certificate holders. Since majority of teacher training institutions in South Africa are now offering B Ed degrees or PGCEs, it revealed to us that the majority of teachers surveyed had their training more than 15 years ago. The study thus noted that the implications are that if these teachers are not active in in-service training programs, they are less familiar with new trends and latest teaching strategies such as the use of various visualization strategies that have gained recognition in the last five or so years.

**Table 2: Teaching experience of participants**

| Teaching experience ($x$ years) | Less than 5 | $5 \leq x < 10$ | $10 \leq x < 15$ | $15 \leq x < 20$ | $x \geq 20$ |
|---|---|---|---|---|---|
| **Frequency %** | 21 | 10 | 26 | 17 | 26 |

Of the surveyed teachers as shown in Table 2 above, 79% had attained five years or more of teaching experience. Thus, this survey mostly dealt with teachers who had had substantial teaching experience of mathematics at school level. It was thus our assumption that since the majority of teachers had already acquired more experience of teaching mathematics, they had also tested and tried various visual methods of teaching the Pythagoras' theorem. However, this result challenged our assumption and such has been uncovered in some studies that, either being highly qualified or having long years in service does not automatically translate into effectiveness (Spaull, 2013).

***Teacher Training***

**Table 3: Teachers trained to use visuals or not**

| Teacher trained to use visuals | Yes | No | Not sure |
|---|---|---|---|
| Frequency % | 80 | 11 | 9 |

In this study, 80% (see Table 3) of all participants indicated that use of visuals for teaching mathematics was part of their curriculum when they trained as teachers. Some respondents even sighted examples of how they were trained to use visual models to teach the Pythagoras theorem. For example, **Tr19** said, *"we were trained using areas of squares, circles and regular pentagons on the sides of a right-angled triangle in establishing the relationship between the three sides.''* While this raised our hopes that we would find insightful ideas from these teachers' post college/university experiences, the same teachers highlighted that they were not using some of these strategies due to time constraints, lack of resources in their schools, syllabi related constraints among others. Previous studies in South Africa, for example by Gomba (2019) and Spaull (2013) concluded that ineffective teaching coupled with lack of adequate continuous teacher development in the country is behind the predominantly poor performance in school mathematics and science.

During interviews, **TB** explained his experiences after the workshop, "*While I remember being taught how to use manipulatives when I was at college, it was not on Pythagoras theorem. Thus this workshop has helped me on how to use visual now on Pythagoras theorem.*" **(Interview, $TB_1$).** Such responses indicated to us that while the training was done then, very little in-service programs later supported these teachers on how to use visual strategies in mathematics classes. In South Africa, Gomba (2019) found that lack of continuous teacher development in schools is one of the major causes of poor performance by learners.

### *Teacher use of visual models*

**Table 4: Teacher uses visual models or not**

| Teacher uses visual models | Yes | No |
|---|---|---|
| Frequency (%) | 76 | 24 |

In this study, 76% (see Table 4) of all participants indicated that use of visuals for teaching mathematics was part of their curriculum when they trained as teachers. Some respondents even sighted examples of visuals used and how they use them to assist learners in understanding various mathematical concepts. However, some said they used them sparingly or did not use visuals at all (see Excerpt 1 below).

**Excerpt 1: Some of the teachers' responses**

| Teacher code | Teacher responses | |
|---|---|---|
| | How I teach Pythagoras' theorem | Prohibiting factors |
| $\boldsymbol{Tr_{27}}$ | *The old-fashioned way. Drawing a right triangle on the board with a missing side then apply the formula.* | *Lack of electricity in our school* |
| $\boldsymbol{Tr_{53}}$ | *Its conceptualization of formula and application of formula to solve problems.* | *Time consuming and syllabi to be finished.* |
| $\boldsymbol{Tr_{79}}$ | *I only use the given information to substitute and find the missing information.* | *I was never shown how.* |
| $\boldsymbol{Tr_{81}}$ | *I draw a scale triangle* | *Lack of resources like teaching aids, ICTs and projector.* |
| $\boldsymbol{Tr_{86}}$ | *Stating the formula, doing a few problems and giving them similar problems to try out.* | *There is always pressure on the completion of the syllabus. It is also difficult to use.* |

Those who said they do not use visuals (24% see Table 4) highlighted the challenges associated such as time constraints, DBE's strict adherence to the pacesetter and lack of support from subject advisors, lack of suitable equipment in the school, among others.

### Emerging themes

#### *Perceptions relating to teacher practices*

Some teacher perceptions relating to their practice emerged from this study. Figure 1 shows that 26% of the surveyed teachers considered a good mathematics teacher as one who use visual aids in every lesson. In this same district, 66% believed that good mathematics teachers are characterized by sequential and logical teaching. This indicated to us that most teachers in the district still emphasize rote and algorithmic approaches at the expense of other approaches such as visualization strategies.

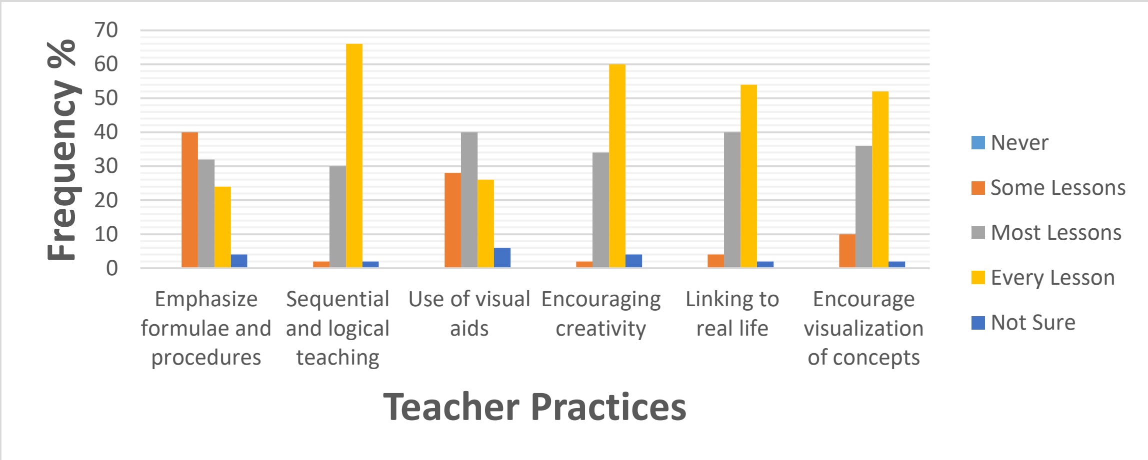


***Figure 1: Good mathematics teacher practices***

We also noted that 68% of the surveyed teachers (see Figure 1) were of the opinion that a good teacher uses visuals in some or most lessons but not necessarily every lesson. Such a result tallies with what Boaler et al., (2017) and Tanton (2016) that powerful mathematics teaching and thinking is in the use of visuals. While teachers are keen to use visual tools and strategies in their teaching, it appears that they experienced some constraints that may need to be identified and addressed.

After the second workshop, **TC** said, "*my thinking has shifted on Pythagoras' theorem because I now have more insights as to how I can incorporate some visuals from my learners' home backgrounds to improve my teaching*." (**Interview, TC$_1$).** Such experiences as indicated by **TC** revealed to us that some teachers had benefited from this workshop, especially on how to use visuals to teach Pythagoras theorem. This tally with already established results that continuous teacher development must be encouraged to assist in-service teachers in the work in schools (Gomba, 2019). Jovanova-Mitkovska (2010) reiterates that teacher practices should involve "… daily professional and personal growth … involving training of teachers with new knowledge, skills, strategies in the respective areas of competence and application of appropriate technology" (p. 2925).

***Experiences of using visuals during mathematics teaching***

Figure 2 shows that, on average, 72% of the teachers who responded to the questionnaires were using visual aids in some or most lessons when referring to real life situations while only 12% indicated that they use visuals in every lesson. For example, one of the surveyed teachers, **Tr63**, said, "*In extending mathematics to everyday life, I use real life examples to assist my learners understand and it works very well*." In the interview, **TB** also said, "*I try to find related aspects outside the classroom that may illustrate a concept. It is not always easy but doable*." (**Interview, TB$_1$**).

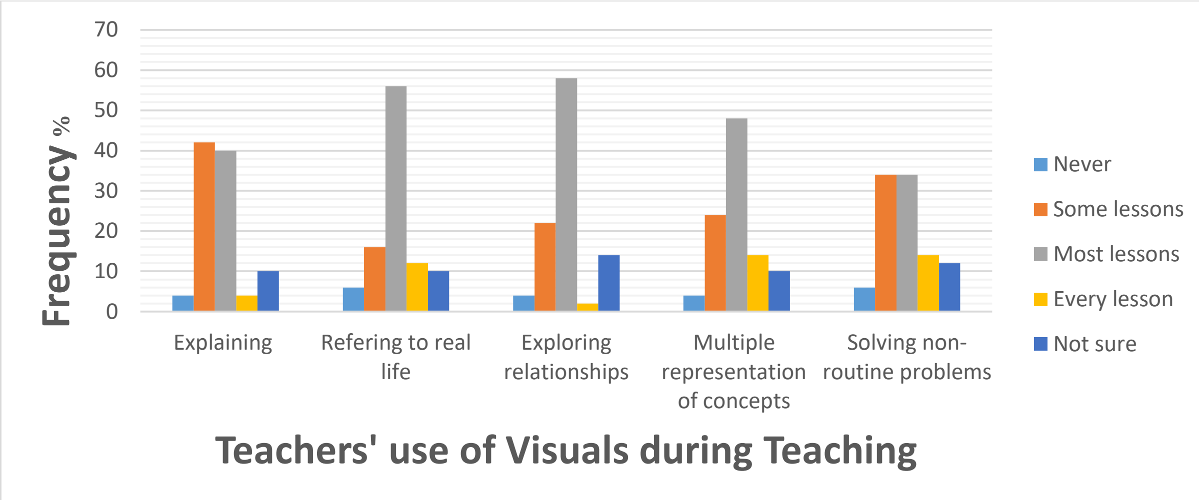


***Figure 2: Frequency of a teacher's use of visuals during the lesson.***

Teachers' making connections to everyday lives of their learners was evident in their responses and lessons observed. Kilpatrick et al, (2001) posits that when teachers are able to connect mathematics to the outside world to help learners to make sense of what they are learning and to solve real world problems, conceptual understanding is promoted. Also, use of these everyday examples help teachers to make links between the mathematics, learners' prior knowledge and experiences which are necessary elements for enhancing conceptual understanding.

In illustrating the Pythagorean concept **TA** said, "*I took a right triangle pasted it on the chalkboard with squares that fit on the respective sides, learners were able to count the number of squares in each square and by doing so they were able to establish a relationship between the sides (***Interview TA1***).''* This highlighted to us that in demonstrating Pythagoras' theorem, this teacher linked Pythagoras' concept to area. **TA** used visuals to establish connections between the concept of area and Pythagoras' theorem. This competence in making such mathematical links and connections to other domains of mathematics is one of Kilpatrick et al (2001)'s significant pointers for conceptual understanding. We assert that the use of different visual approaches is essential for enhancing conceptual understanding of mathematical concepts (Arcavi, 2003). Although visualization has the high potential to aid teachers in promoting conceptual understanding during teaching, teachers in the surveyed district currently incorporate visual strategies sparingly for solving non-routine problems and representing concepts in multiple ways.

**Summary and conclusion**

The use of visuals was generally seen as a positive when teaching Pythagoras theorem and MWPs. In our analysis, various conceptual understanding themes relating to how teachers in the district teach Pythagoras theorem and problem solving emerged. These included teachers' ability to build on prior knowledge rooted in everyday life, use of multiple representations and making connections among ideas in mathematics and real life. Survey questionnaire responses revealed that very few teachers use visual aids to assist them extend what they are teaching to real life. Interview revealed that these teachers made use of visuals from learner' context in solving MWPs.

Lack of resources in schools, time constrains and some syllabi related issue were noted as reasons why few teachers were using visualization strategies to make connections among concepts in mathematics. However, findings from interviews revealed that when demonstrating the Pythagorean concept, teachers were able to link concepts like area, exponents that enabled learners to see these connections, thus their learning with understanding. This align with what Hiebert and Carpenter (1992) expound ''that we understand something if we see how it is related or connected to other things we know'' (p. 4). Teachers used visuals to build from what learners already knew. This is in agreement with Arcavi's (2003) assertion that in making links between the known and unknown, the learner can imagine his previous experience or knowledge, impose it on the problem and use it to derive a solution. Interview revealed that teachers made use of visuals to aid them in demonstrating different mathematics ideas, linking them to other mathematical constructs and to real life situations.

While teachers acknowledge the importance and value of visualisation approaches to enhance the teaching of mathematics, many of these teachers are either using visuals minimally or not using at all. The crucial and power of mathematical visualisations (Tanton, 2016) has already been established in previous research (Arcavi, 2003; Boaler et al., 2017; Presmeg, 2006). In this study, we emphasize that teachers need to be made aware and reminded that visualization strategies have the capability to promote teaching for conceptual understanding in science, technology, engineering, and mathematics (STEM) education. An intervention with all the teachers in the district, specifically focusing on the use of visualisation tools and skills to teach specific mathematics topics for conceptual understanding is required. We conclude that there is need for in-service programs and workshops to support teachers on how to efficiently and optimally use visual tools, processes and strategies in mathematics classes. This in turn can be applied to all facets of school teaching in a view to strengthen quality contextualized science, technology, engineering, and mathematics (STEM) education in Africa.

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**Strand 2 # Role of Professional Associations in STEM Teaching and Learning**
1.STEM and Professional Organizations
2.Promoting STEM education through linkages with Professional Associations

**Article 16**

# Influence of SMASSE on the quality of teaching and learning of mathematics and sciences in public secondary schools in Bungoma county, Kenya

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**Abstract**

Strengthening Mathematics and Science in Secondary Schools (SMASSE), was introduced in Kenya with the aim of improving performance of mathematics and science in secondary schools through encouraging the use of better teaching and learning methods. The purpose of this paper was to determine the influence of SMASSE on the quality of teaching and learning of mathematics and sciences. The study target population of 1,184 teachers teaching mathematics, chemistry, biology and physics from 296 public secondary schools in Bungoma County. The sample size of 299 teachers was arrived at using the Yamane (1967). Stratified random sampling technique was used to select the teachers who participated in the study. The study used a questionnaire as the main instruments of data collection. Piloting was carried out to ensure the research instruments were valid. On the other hand, Cronbach Alpha Coefficient (α) was used to establish whether the instruments were reliable. Quantitative data was analyzed using descriptive and inferential statistics and data presented in frequency tables while qualitative data was presented in narrative form. Hypothesis was tested using linear regression at 0.05 level of significance to determine the degree and direction of relationships among variables. The study attained Cronbach Alpha of coefficient of 0.803 for all the questions on SMASSE. From the research findings, mathematics and sciences teachers should continue giving students assignments that need to be discussed in groups to enhance learning. Use of PDSI and ASEI should be encouraged in schools since it positively influences quality of learning in secondary schools. Schools administration need to proactively sponsor mathematics and sciences teachers to go for SMASSE INSET. Teachers need to engage students to present activities in class during mathematics and sciences lessons to enhance quality of learning. The study recommends for the ministry of education to equip schools with necessary teaching and learning resources to boost the quality of mathematics and science subjects.

**Key words**: *SMASSE, Quality teaching and Learning, Public Secondary schools, Bungoma County*

## Background

SMASSE is abbreviation for; Strengthening of Mathematics and Science in Secondary Education which is an educational program whose aim is to help improve the performance of Science and Mathematics in Kenyan secondary schools. It is a joined venture between the Kenya Government through Ministry of Education, and Government of Japan through Japanese International Corporate Agency (JICA) initially on pilot basis. SMASSE came into being when the consistently poor performance in Mathematics and Science (Biology, Chemistry and Physics) became a matter of serious concern (Republic of Kenya, 2005). Broad curricula, lack of facilities and inadequate staffing were always cited as the major causes of the problem. Although dismal performance in these subjects had almost been accepted as the norm in some schools, the Ministry of Education and other stakeholders felt the need for an intervention, hence the Strengthening of Mathematics and Science in Secondary schools (Nui & Wahome, 2006).

The SMASSE program was implemented over a 10 year period (from 1998 to 2008), with marked strides. In the first phase of the project (June 1998 – June 2003), activities were initiated on a pilot basis in nine (9) Districts (Butere, Mumias, Gucha, Kajiado, Kakamega, Kisii, Lugari, Makueni, Maragua and Murang'a). Six additional districts (Baringo, Garissa, Kiambu, Kilifi, Meru South and Taita Taveta), were brought on board in 2001, bringing the number of districts in the pilot phase to 15. The second phase was implemented from July 2003 – June 2008, on national scale. By the end of the project, a total of 108 district centres for In-Service Training (INSET) had been established in public secondary schools throughout the country Centre for Mathematics, Science and Technology in Africa (CEMASTEA strategic plan 2009 – 2013). Interviews on causes of poor performance in Mathematics and Science subjects were conducted for Head teachers, teachers, students, parents and laboratory assistants. More data was collected by administering questionnaires to teachers and students, lesson observation and video recording of lessons for further observation.

The baseline survey study of 2009 showed that mathematics and science education were encountering challenges. Many teachers showed poor content mastery or lacked practical skills and innovativeness. They also used inadequate or poor teaching methods. The teachers were using theoretical, teacher centered approaches in teaching or lecture methods, instead of the hands-on approach. The teacher, the baseline survey revealed, had little or no lesson plans. Teachers missed lessons and there was acute lateness to schools and to classes in addition to lack of giving exercises to the learners by teachers.

SMASSE (2004) stated that SMASE's project main activity was INSET for serving mathematics and science teachers so as to reduce/eradicate contributory factors of poor performance in these two subjects as outlined by the Baseline Survey of 2009 undertaken by JICA. The SMASE programme chose to address only those challenges that were within its ability of solving such as; Teachers and Pupils/learners attitude towards mathematics and science, teaching methods used by teachers-pedagogical skills, content taught and its understandability to learners and mobilization and management of resources.

**Statement of the Problem**

Despite the rationale for SMASE programme on the enhancement of mathematics and sciences, learner's performance for a long time has continued to be low. The problem has been that factors influencing learner's performance in mathematics and sciences have not been well conceptualized not only at national level but also in Bungoma County, Kenya. Among the challenges encountered is the quality of teaching which needs to be strengthened and made more effective. Instructions by teachers to learners hardly dwell on design, use of locally available resources or on student's real life situations to improve on teaching materials that enhance learner's participatory skills. Mathematics teachers in secondary schools in Kenya and specifically Bungoma County have been trained on the application of SMASE approaches such as Activity, Student, Experiment Improvisation (ASEI), Plan, Do, See and Improve (PDSI) among others however, it has been found out that that what teachers learn during SMASE INSETs is sometimes not used back in the schools. It is only a few lessons that could be classified as tending towards learner centered approaches. A Baseline Survey conducted in 2011 revealed that over 80% of the lesson time was dedicated to giving verbal instructions and theoretical teaching in cases that needed practical or hands- on activities. It was against this that the present study aimed to establish the influence of SMASSE on the quality of teaching and learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya.

**Objective of the study**

The general objective of the study was to establish the influence of SMASSE on the quality of learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya.

**Research Question**

What is the influence of SMASSE on the quality of teaching and learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya?

**Literature review**

Background to the SMASSE project in Africa is the Jomtein declaration of education for ALL (EFA) in 1990 that marked a shift of Japans focus from "hardware" type of projects - for example - the supply of buildings to schools, to "software" type of projects. Furthermore, at the United Nations general conference of trade and development (UNICTAD in 1996), Japan expressed her interest towards supporting education activities in Africa through a paper that was then presented during the 7th SMASSE-WESCA annual conference which was held in Lusaka, Zambia. JICA recognized Africa's need for assistance when it came to improving: the quality of education; the training of teachers; and the administration & management of schools. Japan is familiar with the concept of in-service training of teachers and further more is experienced in linking that which is taught in mathematics to that which is taught in science. This was so as to ensure that mathematical and sciences concepts learned, had an industrial applicability and also thus enhancing a graduate's employment ability. It had also been credited with the identification of that unique approach which saw industrial practices reformed through lesson studies. Within the same background, Africa's initiative - in which Japan plays an important role -, sought to not only strengthen mathematics but also to enhance the ability of students, but now through improving the mastery of content by teachers and also their mastery of pedagogical skills. According to Hosstein, (2005), the initiatives of SMASSE-Kenya; SMASSE- Nigeria; SESEMAT-Uganda and SMASSE-Zambia all involve the strengthening of mathematics and sciences at the secondary level of education.

Globally, several studies have been done on the influence of SMASSE on the on the quality of learning of mathematics and sciences in public secondary schools. Oirere (2008) found out that in Kenyenya Division, Gusii, 70% of teachers attended the SMASE INSET voluntarily and so had a positive attitude towards SMASE INSET, in the desire to improve methodology, certification and promotion. These teachers were implementing the ASEI-PDSI lesson planning techniques although without physical lesson plans. Kamunyu (2011) notes that it would seem that teachers in diverse areas of Kenya have varied attitudes towards SMASE INSETS. It is for this reason that this study aimed to establish the influence of SMASSE on the quality of learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya.

A study by Kagenyi (2007) in Kiamwangi Division, Muranga showed that 63% of teachers in the division did not like attending the SMASE INSET training. As such, teachers' attitude to SMASE was negative, 43% of teachers, 40% of principals /head teachers and 100% of trainers agreed that SMASE had changed their attitude towards mathematics. The study showed that most teachers were not motivated to attend the SMASE INSETS. The present study sought to establish the influence of SMASSE on the quality of learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya.

Owiti (2011) observed the results of the Third International Mathematics & Sciences study (TIMES) of 1996 that had revealed the existence of a level of mediocrity when it came to teaching and learning mathematics that was simply intolerable. Teaching and learning mathematics basically entailed: the review of homework from the previous lesson; the issuance of more assignment; a quick delivery of a set of rules & the lesson in general; and finally, blowing away the remaining time with a set of exercises that teachers regarded to be for practice

Nui and Nyachomba (2006), in the report at the 4th workshop on effective operation and management of SMASSE project in 2004 noted that more reforms are expected in reference to SMASSE INSET, such that learners were to become active in the learning process as the teachers guided the learning process. It was also recommended that the attitude of teachers and learners towards learning/teaching of mathematics be positive. In addition, teachers were to practice more effective teaching and learning methodologies and also possesses content masterly to boost confidence in teacher/learner. The present study sought to establish the influence of SMASSE on the quality of learning of mathematics and sciences in public secondary schools in Bungoma County, Kenya.

**Methodology**

The study used of descriptive survey research design and Correlation research design due to their ability to consider diverse aspects of the research problem. Mugenda and Mugenda (2003) define survey research as an attempt to collect data from members of a population in order to determine the current status of the population with respect to one or more variables. The survey strategy involves research in which sample surveys are selected to represent a known population. The sampling survey allows the researcher to generalize a study's results to a known population. Data was collected directly from the respondents using a systematic technique (questionnaire or interviews). The basic reasons for choosing survey strategies include the fact that a sample is chosen in such a way as to allow generalization to a defined population, results are accurate because of a large sample size and generally low sampling error. Data collection takes place in a natural setting and data is obtained directly from respondents.

**Study Population**

The population composition is 48% male and 52% female with a population distribution of 435.5 per $km^2$ with a population growth rate of 43%. This represents 36% of the national population. It borders Busia, Kakamega and Trans Nzoia Counties. The County has nine sub-Counties, six municipalities and seven constituencies. The area coverage for the County is 2,206.9 $km^2$ (852.1 sq miles). The climate of the County favours Agriculture as temperatures range between a minimum of 15 degrees and 30 degrees centigrade with an average rainfall of 1500 mm. The County has 296 public secondary schools. The literacy level is 60.5% with those attending school (15 yrs-18 yrs.) at 87.4% with secondary school enrolment of 130,907 students. The target population from which the study sample was drawn was 296 teachers of mathematics and Science subjects from each school and 296 form four students. Stratified simple random sampling was used to select one teacher from each school teaching either mathematics or sciences subjects.

**Research instruments**

Questionnaires were used since the study is concerned with variables that cannot be directly observed such as views, opinions, perceptions and feelings of respondents. The sample size is also quite large, given time constraint; questionnaire is the ideal tool for collecting data. The target population being largely literate was unlikely to have difficulties responding to questionnaire items. The questionnaire was used to mainly collect quantitative data.

**Piloting**

Six public secondary schools in Trans Nzoia County were randomly selected for pilot testing. Six science and mathematics teachers were requested to carefully fill the questionnaires under the guidance of the researcher through direct contact at agreed dates. After pilot testing of the instrument on the proposed number of people, the researcher looked at the pattern in the feedback and used the data to revise the instrument. A test retests method on sample of at least ten respondents is adequate (Mulusa, 1988). The test retest method helps to point out deficiencies in the instruments and identifies questions that are vague. This enhances the reliability of the instruments. In this study, 10 respondents representing the two categories of respondents in terms of teaching either mathematics or science subject from Trans Nzoia County were requested to respond to questionnaires a second time after two weeks and the correlation between the two set of scores were computed by comparing the two scores with Cronbach Alpha Reliability coefficient.

**Data analysis**

In this research, the study questionnaire was adequately checked for credibility and verification. Coding of the data was done at this point. Quantitative data collected was analyzed with the aid of Statistical Package for Social Sciences (SPSS version 21). The findings were presented/ distributed in summary using percentages, ratios and frequency distribution tables for quantitative data.

**Data analysis and Discussion of the Findings**

The respondents were categorized into two sections; teachers and students who were randomly selected from the 296 schools in Bungoma County, Kenya. From the findings, 275 students responded to the questionnaire supplied to them. This translated to 92.9% questionnaire return rate, which was considered adequate for the study. The questions regarding SMASSE project were asked to both teachers and students. They were put on a five point Likert scale where; Strongly Disagree (SD)=1, Disagree (D)=2, Not sure (NS)=3, Agree (A)=4 and Strongly Agree (SA)= 5. The response from the students on various statements was as summarized in table 4.1.

**Table 4.1 Summary of SMASSE Project on teaching Mathematics and Sciences**

| Statements | SA f(%) | A f(%) | NS f(%) | D f(%) | SD f(%) |
|---|---|---|---|---|---|
| Our teacher starts a lesson by reviewing previous lesson | 152(55.3) | 105(38.2) | 0(0) | 6((2.2) | 12(4.4) |
| We are encouraged by our mathematics and science teachers to form groups for discussion purposes | 131(47.6) | 120(43.6) | 0(0) | 6(2.2) | 18(6.5) |
| Our mathematics and science teachers use prepared notes to teach us | 140 (50.9) | 129(46.9) | 0(0) | 0(0) | 6(2.2) |
| Our mathematics and science teachers allows us to present activities in class | 76(27.6) | 97(35.3) | 33(12) | 10(3.6) | 59(21.5) |

| | | | | | |
|---|---|---|---|---|---|
| Our teachers gives us assignments | 82(29.8) | 157(57.1) | 0(0) | 0(0) | 36(13.1) |
| The school has enough teaching and learning resources for mathematics and science subjects | 96(34.9) | 143(52) | 30(10.9) | 0(0) | 6(2.2) |
| Summary of what has been learnt is done by our teachers at the end of the lesson | 147(53.3) | 91(33.1) | 11(4.0) | 6(2.2) | 20(7.3) |

From the research findings, 152 (55.3%) of the respondents strongly agreed the teachers start their lessons by reviewing previous lessons, 105 (38.2%) agreed while the remaining 18 (6.6%) disagreed. From the results, 131 (47.6%) of the respondents strongly agreed mathematics and sciences teachers encourage them to form group discussions, 120 (43.6%) agreed while the remaining 24(8.7%) disagreed. Majority of the respondents agreed mathematics and science teachers encourage the students to form groups for discussion. The results showed 140 (50.9%) of the respondents strongly agreed their mathematics and sciences teachers prepare notes for teaching, 129 (46.9%) agreed while the remaining 6 (2.2) disagreed. Majority of the respondents agreed their teachers prepare notes for teaching. Out of 275 respondents who participated in the study, majority of the respondents 176 (62.9%) of the respondents agreed mathematics and science teachers allow them to present activities in class, 33 (12%) were not sure while the remaining 69(25.1%) disagreed. On whether the teachers give students assignment or not, out of 275 respondents who participated in the study, 82(29.8%) strongly agreed, 157 (57.1%) agreed while the remaining 36 (13.1%) disagreed the teachers give them assignment. From the results, majority of the respondents 239 (86.9%) agreed the school has enough teaching and learning resources for mathematics and science subjects, 30 (10.9%) were not sure while the remaining 6 (2.2%) strongly disagreed. The findings further revealed that 147 (53.5%) of the respondents strongly agreed the teachers prepare summary of what have been learnt at the end of the lesson, 91 (33.1%) agreed, 11(4%) were not sure, 6 (2.2%) disagreed while the remaining 20 (7.3%) strongly disagreed.

The study further established from the teachers the use of SMASSE project. Summary of the findings was as shown in Table 4.2

**Table 4.2 Use of SMASSE project by Mathematics and Sciences Teachers in Secondary Schools.**

| Statements | SA f(%) | A f(%) | NS f(%) | D f(%) | SD f(%) |
|---|---|---|---|---|---|
| Do you enjoy attending SMASSE INSET | 136(49.5) | 124(45.1) | 7(2.5) | 8(2.5) | 0(0) |
| SMASSE INSET trainers are competent | 155(56.4) | 85(30.9) | 5(1.8) | 6(2.2) | 24(8.7) |
| SMASSE should be continuous | 221(80.4) | 36(13.1) | 18(6.5) | 0(0) | 0(0) |

The study further established from the teachers, the response on SMASSE quality. The results revealed that majority of the teachers 260 (94.6%) enjoy attending SMASSE INSET, 7 (2.5%) were undecided while the remaining 8 (2.9%) disagreed. Out of 275 respondents who participated in the study, 155 (56.4%) strongly agreed SMASSE trainers are competent, 85 (30.9) agreed, 5 (1.8%) were not sure while the remaining 30(10.7%) disagreed. Majority of the respondents agreed SMASSE trainers were competent. From the findings, majority of the respondents, 257 (93.5%) agreed SMASSE INSET should be continuous while the remaining 18 (6.5%) disagreed.

The study further established the frequency of use of both PDSI and ASEI by the teachers. The results revealed that out of 275 teachers who participated in the study, 104 (37.8%) use PDSI very often, 127 (46.2%) often use PDSI, 24 (8.7%) rarely use PDSI while the remaining 20 (7.3%) very rarely use PDSI. On the other hand, 64 (23.3%) very often use ASEI, 123 (44.7%) often use ASEI, 48 (17.5%) rarely use ASEI, 31 (11.3%) very rarely use ASEI while the remaining 9(3.3%) do not use ASEI at all. Summary of the findings were presented in Table 4.3.

**Table 4.3 Use of PDSI and ASEI in Teaching Mathematics and Sciences**

| Statements | VO f(%) | O f(%) | R f(%) | VR f(%) | NA f(%) |
|---|---|---|---|---|---|
| How often do you use PDSI | 104(37.8) | 127(46.2) | 24(8.7) | 20(7.3) | 0(0) |
| How often do you use ASEI | 64(23.3) | 123(44.7) | 48(17.5) | 31(11.3) | 9(3.3) |

**Key: VO=Very often, O=Often, R=Rare, VR=Very Rare, NA=Not at All**

The findings are in agreement with the aims of SMASSE which were to;

a) Upgrade teacher's content in their subject areas and provide forum for mathematics/science teachers to meet and exchange ideas and experiences through peer teaching and lesson observation.

b) Develop good work plan through ASEI/PDSI approach as a way of ensuring well utilization of available resources in terms of money and time and identifying ways of creating and sustaining interest.

c) Bringing about attitude change in the mathematics/sciences among education stake holders, policy makers, administrators, teachers, learners and parents.

d) Equipping District Trainers with skills of carrying out situational analysis in their respective districts and to develop a curriculum addressing their needs/Gaps.

e) Equipping teachers with skills for proper use of innovations as a problem solving in this era of 21st century which is characterized by technological changes.

f) Provide Mathematics/Science teachers a chance for self-professional development which is one of the requirements for the teacher under Teachers Service Commission (TSC) as stipulated by the new constitution.

g) Identifying and equipping one school per district with necessary reagents, chemicals, apparatus and teaching tools where all the other schools in the district can access them.

**Summary, Conclusions and Recommendations**

From the research findings, mathematics and sciences teachers should continue giving students assignments that need to be discussed in groups to enhance learning. Use of PDSI and ASEI should be encouraged in schools since it positively influences quality of learning in secondary schools. Schools administration need to proactively sponsor mathematics and sciences teachers to go for SMASSE INSET. Teachers need to engage students to present activities in class during mathematics and sciences lessons to enhance quality of learning. The study recommends for the ministry of education to equip schools with necessary teaching and learning resources to boost the quality of mathematics and science subjects.

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**Article 17**

# Exploring factors affecting students' attitude towards mathematics: A case of Mayuge district in Uganda

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**Abstract**

Mathematics attainment in sub-Saharan Africa is very low in universal terms and students' attitude towards the subject cannot be disputed as causative. This study explored the factors affecting students' attitude towards mathematics in Mayuge District in Uganda. A total of 247 students filled a Mathematics Attitude Survey and five head teachers were interviewed. Using descriptive statistics, student sample t test, categorization and thematic analysis, results indicated that students had an undecided attitude towards mathematics with an overall mean of 3.44 and there was no significant gender difference in the mean scores on students' mathematics attitude. The factors that affected the students' mathematics attitude were students themselves, teachers, social economic status, the school as a learning environment and nature of mathematics. These findings provide a foundation on which further interventions by funding bodies who share in promoting STEM education in low income countries can be anchored.

**Keywords:** *ABC model, Attitude towards Mathematics, ISP, Mayuge, Uganda*

**List of Abbreviations:** *EANWOBAS-Eastern Africa Network of Women in Basic Sciences, ISP-International Science Programme, UGAWOM-Uganda Women Mathematicians*

## Introduction

Mathematics attainment by students in countries within Sub Saharan Africa (SSA) is graded far below the average point in international assessments (Bethell, 2016). Moreover, mathematics is one of the core mandatory subjects to all students in primary and lower secondary school levels in Uganda. Yet, students consistently perform poorly in this subject, which in turn severely restricts their access to economic and personal thriving in a global 21$^{st}$-century. Given the constrained resources available to the government of Uganda and increased demands by the people, it's now inevitable for the private sector to get involved in the provision of educational facilities in the country (Nsiah, 2004). Thus, several professional associations both local and international have come on board to promote education through linkages between themselves and schools, for example, ISP, EANWoBAS, UGAWOM among many more. ISP funded EANWoBAS/

UGAWOM in March 2019 to visit Mayuge District to serve as role models in mentoring girls into science and mathematics, targeting hundreds of primary and secondary school students in the district with the hope that mathematics and science achievement would be enhanced.

According to the international coordinator of ISP funding in Uganda, who is also one of the authors of this article, "one reason for encouraging girls to choose to study physics and mathematics at university level is the current lack of female role models, and female teachers in these subjects are rare in primary and secondary schools" (2019, n.d.). The choice of Mayuge District among others based on its registration as one of the districts in the country with the lowest levels of science and mathematics achievement.

For meaningful mentorship, we explored the students' attitude towards mathematics. While McLeod (1992) defined attitude towards mathematics as an emotional response that embodies simple positive and negative feelings and involves rational stabilities, Hannula (2002) accentuated that attitude encompasses three components namely emotion, belief and behavior. Meanwhile, Di Martino and Zan (2011) integrated the cognitive component in the definition and therefore, we can perceive attitude towards mathematics in terms of three components namely affective (emotions and beliefs), cognitive and behavior (Ayob & Yasin, 2017). In accordance, this study was grounded in Ajzen's (1993) Affective, Behavioral and Cognitive (ABC) model to explore the students' attitude towards mathematics. Several studies (e.g. Ayob & Yasin, 2017; Davadas & Lay, 2018; Elci, 2017; Izadi, Hadipour & Ahmadabadi, 2018; Kasimu & Imoro, 2017; Mazana, Montero, & Casmir, 2019; Otoo, Iddrisa, Kessie & Larbi, 2018; Simegn & Asfaw, 2017) have examined the factors affecting students' attitude towards mathematics.

However, apart from only two studies (Davadas & Lay, 2018; Mazana *et al.*, 2019) all the other studies did not use theories to explain the phenomenon of students' attitude towards mathematics. Further, the reviewed studies present contradictions on gender differences in attitude towards mathematics. While some (Kasimu & Imoro, 2017; Simegn & Asfaw, 2017) found no gender differences in attitude towards mathematics, others (Ayob & Yasin, 2017; Davadas & Lay, 2018; Elci, 2017; Izadi *et al*, 2018; Mazana *et al*., 2019; Otoo *et al*, 2018) established the differences. This may suggest that results on gender differences in attitude towards mathematics differ according to time and place. On account of gaps from literature, this study explored students' attitude towards mathematics and the associated gender differences and further used the ABC model to explain the factors affecting teaching/ learning of mathematics in Mayuge District, so interventions for improvement would be rightly thought.

## Materials and Method

*Research Design, Study Population and Sample:* The study employed a mixed methods approach. It applied a cross-sectional correlational survey design for the quantitative research paradigm (Creswell, Klassen, Clark & Smith, 2011) and a phenomenological research design (Astalin, 2013) to understand the factors affecting teaching/ learning mathematics from the students' point of view as well as that of head teachers. Specifically, descriptive phenomenology (Padilla-Diaz, 2015) by which students' personal and head teachers' factors were described and interpreted to understand students' attitude towards mathematics, was adopted. Meanwhile, the population for this study consisted of students in all the 46 secondary schools and the best performing primary school in Mayuge District. Of these, five schools namely: Busoga Secondary School, Waitambogwe Secondary School, Bunya Secondary School, Delta High School and Ikulwe Primary School participated in this study. They were purposively sampled with the guidance of the District Education Officer and selected on condition that they were the best science performing schools in the whole district. These schools had a total population of 4362 students and from these, Krejcie and Morgan (1970)'s table of sample size determination suggested a sample size of 354 respondents who were sampled by simple random sampling (Roy & Zeng, 2014). All these students were given a questionnaire but only 247 returned it filled, implying a response rate of 69.8%.

*Instruments:* The primary instrument for collecting quantitative data in this study was the Mathematics Attitude Survey (MAS), adapted from Code, Merchant, Maciejewski, Thomas and Lo (2016). The MAS comprised 25 self-opinion items and one semi-structured question that requested the respondents to state the factors that affected their learning in mathematics. The reliability test of the instrument gave a Cronbach alpha value of 0.81, which according to Abe and Gbenro (2014), was a good instrument. Data on the background variables of the respondents were collected and included the respondents' sex, class, best subject and their usual mathematics mark. A typical respondent was a girl (54.3%) in S.2 class (21.5%) with her best subject being mathematics (40.9%) and with a usual mark between 60% -79% (36.8). Qualitative data from the head teachers of the five sampled schools were collected from an interview with each of them. The interview had only one semi-structured question which asked the head teachers for their thoughts on factors that affected students' attitude towards mathematics.

*Data Analysis*: The quantitative data were analyzed using descriptive statistics and correlations. At the bivariate level, students' mathematics attitude was related to their gender using student sample t test. Processing of qualitative data from the semi-structured question and interviews involved identification of themes (Lacey & Luff, 2001) through thematic analysis which ensures that clusters of texts with similar meaning are presented together (O'Neil & Koekemoer, 2016). The themes were revised to establish relationships with the data set and then grouped into the constructs of the ABC model.

## Findings

### *Description of Students' Mathematics Attitudes*

The study respondents were asked to rate themselves on mathematics attitude. Each of the items 1 - 22 on mathematics attitude was measured using the five-point Likert scale where 1= Strongly Disagree (SD), 2 = Disagree (D), 3 = Undecided (U), 4 = Agree (A), and 5 = Strongly Agree (SA). SD and D were cumulated to Disagree, U remained unaltered and SA and A were cumulated to Agree. Item 23 was measured using a five-point Likert scale where 1 = Always, 2 = Most of the time, 3 = About half the time, 4 = Once in a while, and 5 = Almost never. Item 24 was measured using a four-point Likert scale where 1 = Very important, 2 = Sort of important, 3 = Not very important, and 4 = Not important at all. Item 25 was measured using respondents' response of either yes or no. Tables 1 and 2 give the descriptive results namely frequencies, percentages and means of the items on students' mathematics attitude.

Table 1: Respondents' Rating on Students' Mathematics Attitude

| Item | Description | Disagree Count (%) | Undecided Count (%) | Agree Count (%) | Mean | Overall Rating |
|---|---|---|---|---|---|---|
| MA1 | Mathematics is enjoyable and stimulating to me | 29 (11.8) | 12 (4.9) | 206 (83.3) | 4.07 | Agree |
| MA2 | Mathematics is not important in everyday life | 169 (72.2) | 18 (7.7) | 60 (20.1) | 2.09 | Disagree |
| MA3 | In mathematics you can be creative and discover things by yourself | 47 (19.7) | 16 (6.7) | 184 (73.6) | 3.78 | Agree |
| MA4 | I have never liked mathematics and it is my most worst subject | 180 (75.6) | 22 (9.2) | 45 (15.2) | 1.98 | Disagree |
| MA5 | There is nothing creative about mathematics; it's just memorizing formulae and things | 101 (42.1) | 22 (9.2) | 124 (48.7) | 3.03 | Undecided |
| MA6 | Students who have understood the mathematics that they have studied will be able to solve any assigned problem in five minutes or less | 37 (15.0) | 07 (2.8) | 203 (82.2) | 4.09 | Agree |
| MA7 | I try to learn mathematics because it helps develop my mind and helps me think more clearly in general | 26 (10.7) | 04 (1.7) | 217 (87.6) | 4.20 | Agree |
| MA8 | Using a computer is a good way for me to learn mathematics | 109 (45.0) | 24 (9.9) | 114 (45.1) | 2.99 | Undecided |
| MA9 | Everything important about mathematics is already known by mathematicians | 47 (19.7) | 20 (8.4) | 180 (71.9) | 3.82 | Agree |

| | | | | | | |
|---|---|---|---|---|---|---|
| MA10 | Mathematics makes me feel uneasy and confused | 160 (67.2) | 19 (8.0) | 68 (24.8) | 2.26 | Disagree |
| MA11 | Mathematics is needed in order to keep the world running | 27 (11.3) | 13 (5.5) | 207 (83.2) | 4.17 | Agree |
| MA12 | Mathematics is a solitary activity done by individuals in isolation | 131 (55.3) | 31 (13.1) | 85 (31.6) | 2.54 | Undecided |
| MA13 | Mathematics is less important to people than art or literature | 164 (68.8) | 28 (11.7) | 55 (19.5) | 2.16 | Disagree |
| MA14 | Mathematics is important for my future profession | 20 (8.4) | 08 (3.3) | 219 (88.3) | 4.36 | Agree |
| MA15 | Mathematics is needed in designing practically everything | 85 (36.2) | 19 (8.1) | 143 (55.7) | 3.25 | Undecided |
| MA16 | Communicating with other students helps me have a better attitude towards mathematics | 25 (10.2) | 11 (4.5) | 211 (85.3) | 4.20 | Agree |
| MA17 | I am interested and willing to acquire further knowledge of mathematics | 10 (4.1) | 06 (2.5) | 231 (93.4) | 4.47 | Strongly Agree |
| MA18 | Real mathematics problems can be solved by common sense instead of the mathematical rules you learn in school | 115 (48.3) | 35 (14.7) | 97 (37.0) | 2.84 | Undecided |
| MA19 | The skills I learn in this class will help me at A level | 13 (5.3) | 04 (1.6) | 230 (93.1) | 4.51 | Strongly Agree |
| MA20 | Ordinary students cannot expect to understand mathematics, they expect simply to memorize it and apply what they have learned mechanically and without understanding | 130 (54.2) | 33 (13.8) | 84 (32.0) | 2.56 | Undecided |
| MA21 | I learn mathematics well from teachers | 32 (13.1) | 14 (5.7) | 201 (81.2) | 4.11 | Agree |
| MA22 | I am good at mathematics | 57 (23.4) | 19 (7.8) | 171 (68.8) | 3.68 | Agree |

| | | |
|---|---|---|
| Overall | 3.44 | Undecided |

Table 1 shows that the overall mean on students' mathematics attitude was 3.44, meaning that the students had an undecided attitude towards mathematics, it was neither positive nor negative. The results in this table also reveal that the students were not sure: whether they found anything creative about mathematics; if mathematics was just memorizing formulae and things; whether using a computer was a good way for them to learn mathematics; if real mathematics problems could be solved by common sense instead of the mathematical rules they learnt in school; and if ordinary students could expect to understand mathematics or simply memorize it and apply what they have learned mechanically without understanding.

Table 2: Respondents' Rating on Students' Mathematics Attitude

| Item | Description | Ratings | Count | Percentage (%) | Mean | Overall Rating |
|---|---|---|---|---|---|---|
| MA23 | During this year, I plan to do the work assigned in the class | Always | 140 | 58.8 | 1.58 | Most of the time |
| | | Most of the time | 71 | 29.8 | | |
| | | About half the time | 18 | 7.6 | | |
| | | Once in a while | 6 | 2.5 | | |
| | | Almost never | 3 | 1.3 | | |
| MA24 | How important is it for you to do well in Mathematics? | Very important | 219 | 92.8 | 1.13 | Very important |
| | | Sort of important | 09 | 3.8 | | |
| | | Not very important | 03 | 1.3 | | |
| | | Not important at all | 05 | 2.1 | | |
| MA25 | I intend to continue with mathematics after S.4 | Yes | 222 | 93.3 | 1.07 | Yes |
| | | No | 16 | 6.7 | | |

Table 2 displays that during this year, students plan to do the work assigned in the class most of the time. When asked how important it was for them to do well in mathematics, the students considered it very important. Regarding the intention to continue with mathematics after S.4, 93.3% of the students were in the affirmative.

*Variations of Students' Mathematics Attitude with Sex*

In this subsection we were interested in finding out whether students' mathematics attitude varied with the respondents' sex. To establish this, a student sample t test was used and the results are presented in Table 3.

Table 3: Student's Sample Test on Students' Mathematics Attitude by Sex

| Sex | Sample Size (n) | Sample Mean | Sample SD | Student's statistics (t) | Sig. or p-value (p) |
|---|---|---|---|---|---|
| Female | 132 | 3.42 | 0.478 | -0.683 | 0.495 |
| Male | 111 | 3.47 | 0.400 | | |

Results in Table 3 show that girls (n = 92) were more than the boys (n = 83). Further, it reveals that on average, the boys (mean = 3.47) rated themselves better on their mathematics attitude than the girls (mean = 3.42). However, basing on the p-value ($p = 0.495$) which was greater than $\alpha = 0.05$ ($p > 0.05$), at the 5% level of significance, the t-statistic ($t = -0.683$) was so small suggesting that the mean scores in Table 3 on students' mathematics attitude by girls and boys did not differ significantly.

Students' responses to the semi-structured question were categorized according to the ABC model. Factors identifying with each ABC construct were isolated. For the affective category, students themselves was identified. While teachers, social economic status and the school as a learning environment were identified in the behavioral category, the nature of the subject was associated with the cognitive category. The highest indicators on the affective category was that students do not see how mathematical concepts are related to the real world and that students found too much pressure for passing examinations. Those on teachers were that: they constantly beat students for failing exercises, tests and examinations and moreover give unclear or no explanations of the mathematical concepts. While failure to pay school fees indicated the parents' social economic status, the failure by schools to give relevant career guidance to the students was the respondents' indicator of the school as a learning environment. According to students, mathematics had too many hard calculations and formulae which are difficult to remember, which indicated the nature of the subject.

In order to enrich survey responses and for purposes of further inquiry, the interview scripts with the five head teachers of the selected schools for this study were analyzed. The head teachers' factors that affected students' attitude towards mathematics were categorized into three themes namely: early marriages, district economic activities and scare science teachers. Girls performing well in science and mathematics subjects are married off even when schools provide bursaries. Meanwhile, during sugarcane harvesting seasons, students stay home to help their parents/ guardians or other village farmers to harvest sugarcanes, to earn some money that they contribute to their schooling and household income. Furthermore, science and mathematics teachers are few in the district and have to teach in all the 46 secondary schools available. Although the selected schools for this study were some of the best performing schools in the district, one of the schools had only one mathematics teacher who taught from Senior One up to Senior Six. The head teacher of this school stated that:

"*I am aware that the mathematics teacher is teaching in more than three schools and this makes him very inefficient in terms of teaching for learning. However, I cannot fire him because I will not have anyone to replace him*"

However, concerning the issue of teachers moonlighting in very many schools at the expense of students' conceptual understanding, the head teachers indicated that the matter was way beyond their control. Some head teachers had employed university students and those who had completed their final A-Level national examinations and waiting to enrol in tertiary institutions, although unqualified, to give assistance in teaching secondary school science and mathematics.

**Discussion**

The results show that the mean score on students' attitude towards mathematics was 3.44, meaning that the students were undecided on their attitude towards mathematics. This in essence means that they neither had a positive nor negative attitude towards mathematics. This finding contradicts Elci (2017), Izadi *et al*. (2018), Kasimu and Imoro (2017), Mazana *et al*. (2019), Otoo *et al*. (2018) and Simegn and Asfaw (2017) who all found positive attitude towards mathematics among the respondents in their studies. Further, the result in Table 3 from the student sample t test on students' mathematics attitude by sex revealed that differences in the mean scores on students' mathematics attitude by girls and boys did not differ significantly and therefore the difference in sample means could be attributed to chance. This finding is in consonance with Kasimu and Imoro (2017) and Simegn and Asfaw (2017) who both found no gender differences among students' mathematics attitude.

The factors, identified with the ABC model, which affected students' attitude towards mathematics included students themselves, teachers, social economic status, the school as a learning environment and the nature of mathematics. When teachers do not give clear explanations of concepts and do not show relationships between these, according to Elci (2017), students might think of mathematics as combining discrete concepts and formulae as was the case in this study. Further, the students' undecided attitude towards mathematics largely stems from the teachers' pedagogical practices. For example, we see that students have difficulties in realizing how mathematical concepts are related to the real world, which directly reflects on the teachers' role. Accordingly, because students revere and strive to emulate the teachers' indisputable role as role models, teachers should work towards supporting and helping them to visualize the usefulness of mathematics both for school and adult life. In affirmation, Davadas and Lay (2018), Mazana *et al*. (2019), and Ayob and Yasin (2017) found that teachers' affective support; teachers' didactic strategies; teaching practice and teachers' quality respectively influence students' attitude towards mathematics. In accordance, Otoo *et al*. (2018) contend that students' perception of the usefulness of mathematics affect their confidence and motivation directly in studying mathematics. Additionally, given that students nowadays are exposed to technology, teachers may consider replacing the traditional chalk and talk teaching method with interactive and activity based methods of teaching to seize the curiosity of the students.

The results further indicate that the head teachers were in such vulnerable positions where even when they were aware of the ambiguities in teaching/ learning mathematics, they could not dispense the mathematics teachers due to their scarcity in the district. It is clear that some of the challenges that these students faced, for example the early pregnancies, the working students and questionable teaching strategies of scarce science and mathematics teachers, were beyond their control. However, owing to the fact that schools are not powerless in affecting beliefs and behaviors of parents who also influence students' learning and development, schools should come with sensitization programs to encourage parents' participation in their children's studies. Further, mathematics teachers should design classroom instruction with the intention of reducing the cognitive burden confronted by students (Otoo *et al*., 2018). We get the feeling that as indicated in Table 2, there was a desire by the students to please the EANWoBAS team. For example, 93.3% of the students said they will continue with mathematics after S.4, yet only 36.8% indicated their usual mark as 60-79% and the majority of the rest usually scoring below 40%. It could also be that since the questionnaires were filled in with the help of classroom teachers, who translated English to their local language – lusoga, they feared that they could be beaten if they indicated otherwise.

The semi-structured question was responded to in the absence of the teachers and it is easy to discern that students were free to submit their challenges. All the schools we visited lacked enough scholastic materials to the extent that even at A-Level, the schools lacked textbooks for the science based students, who only relied on the teachers' class notes. According to one head teacher, "students kept failing especially in science and mathematics because of scarce teachers and high rates of poverty". School fees by the majority parents was a challenge and their children were usually sent back home, making them fail to attend lessons especially for the few times the science teachers were around. On this note, through ISP funding 25 girls were given scientific calculators and each of the four sampled secondary schools got two advanced level textbooks, one for mathematics and the other for physics. The support fund from Uganda Ministry of Education and Sports was used to purchase geometry sets and a total of 338 sets were given to the students in the participating schools.

## Conclusion

The students' attitude towards mathematics was undecided and there were no gender differences between the mean scores on students' attitude towards mathematics for girls and boys. Through the lens of ABC model, four factors that aligned to the affective, behavioral and cognitive components were identified. These were students themselves, teachers, social economic status, the school as a learning environment and the nature of mathematics respectively. Although all these factors impacted students' attitude towards mathematics, teachers were identified to be the most important factor. Teachers' contribution to learning in the classroom and their behavior if worked out in Mayuge District, the students' attitude towards mathematics could be raised to a sufficient level. Furthermore, teaching of mathematics should be focused towards making students understand and perceive the usefulness of mathematics because good knowledge of the usefulness of mathematics upsurges the confidence levels among students. Therefore, mathematics teachers should introduce students to real world applications of mathematics to escalate their knowledge of its usefulness and also set up learning experiences that are enjoyable and interesting so that students may get the sense of accomplishment. Based on the findings from this study, mathematics teachers should alter their teaching methods, giving particular attention to the active participation of students and to facilitate students' understanding and sustainability of their interest in mathematics.

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**Article 18**

# Promoting entrepreneurial mindset development amongst high school learners in Kenya: A pilot project through partner organizations

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**Abstract**

Unemployment rate in Kenya has escalated as more people graduate faster than the number of jobs created. Hence, there is need to equip young people with entrepreneurial skills at an early age. Literature showed that there was no online entrepreneurship challenge for learners. In filling this gap, in 2019 Allan & Gill Gray Philanthropy and its partners - mandated to work with secondary/high schools - piloted the online six-weeks Allan Gray Entrepreneurship Challenge. Every week, learners got a set of challenges that stimulated them to think like entrepreneurs. A total of 141 public and private schools, with computers and internet connectivity, were mobilized to participate (significantly surpassing the pilot target). Key lessons identified were a) collaborating with partners is a strategic means of rapidly reaching and stimulating learners; b) there is a desire for entrepreneurial mindset development amongst learners; an asset which should be nurtured; and c) learners have better access to devices whilst in school. Regarding policy implications, the pilot lessons are expected to incentivise policy makers and stakeholders to fast-track creating conducive environments for intensively nurturing young people's entrepreneurial spirit and/or innate talent at an early age.

**Key words:** *Entrepreneurial mindset development; entrepreneurship skills; entrepreneurial spirit; learners; partnership; Kenya*

**Abbreviations:** *AGEC-Allan Gray Entrepreneurship Challenge, AGGP- Allan & Gill Gray Philanthropy, CEMASTEA- Centre for Mathematics, Science and Technology Education in Africa, MoE- Ministry of Education, KAIS- Kenya Association of International Schools, KPSA-Kenya Private Schools Association*

## Introduction

The rate of unemployment in Kenya has escalated over the years and is set to worsen in the future. The number of young people seeking jobs after completing their formal education is on the raise as more people enrol into tertiary education facilities. According to a report by the British Council, the current education and training system in Kenya is not sufficient in preparing young people for the market (Hall, 2017). Most learners in Kenya are not well equipped with the skills and knowledge needed to become entrepreneurs after graduating (Langat, 2018). This, therefore, leads to increased numbers of unemployed young people in Kenya as most seek formal employment.

With the onset of the 4th Industrial Revolution, and as Kenya develops and embraces automation, technology and artificial intelligence, the number of people needed to deliver a certain task is reduced, and the way people work, think, and learn will change. The narrative can, however, be changed by nurturing entrepreneurial mindsets among young people (Farr, 2014), and create a condusive environment that welcomes entrepreneurs (Nkontwana, 2017) as entrepreneurship creates jobs. This will instil skills that will help more young people survive in the evolving economic world and change their thinking to being job creators; not only job seekers.

Today’s young people need to be prepared to survive and thrive in the fast-paced, ever changing world of business (Dermol, 2017). This calls for a change in their way of thinking and perceiving the world of work. To do so, there is need to change the mindset and behaviour of young people to enhance their entrepreneurial skills (Langat, 2018). According to Farr (2014), entrepreneurial behaviour is the ability of an individual to turn an idea into action.

A country’s ability to develop and maximize on human capital is dependent on change on mindsets and being entrepreneurial literate. Entrepreneurial literacy brings about aspects of critical thinking, problem solving and adaptation skills that can be applied in the future (Farr, 2014). There is, therefore, need to promote entrepreneurial mindset development among young people in the country.

## Preparing for the 4th Industrial Revolution

In the next 10 years, 1 in 5 jobs that exist today will no longer exist. Most will be mechanized and computerized and will not need human labour. The number of people set to lose their jobs in future will increase as most companies and organizations will scale down or advance in technology and no longer need the manpower they have (Dermol, 2017). A major challenge in education today is preparing young people for the future. Based on these scenarios, there is need to better equip young people so that they are better prepared for the future.

## Purpose of the pilot

A scoping exercise was conducted in August and September 2018, which showed that there was no online entrepreneurship challenge open to secondary/high school learners in Kenya (Kareithi, 2018). Allan & Gill Gray Philanthropy (AGGP) aims to fill this identified gap and contribute to entrepreneurial mindset development by changing the narrative through providing secondary/high school learners in Kenya with the opportunity to explicitly develop their entrepreneurial skills from an early age. The organization is doing so through an online six-weeks experiential learning Entrepreneurship Challenge, known as the Allan Gray Entrepreneurship Challenge (AGEC), which seeks to unlock the potential of aspiring high school entrepreneurs (Allan and Gill Gray Philanthropy, 2019).

This is the beginning part of Allan & Gill Gray Philanthropy's long-term strategy in developing exceptional value-driven, high-impact responsible entrepreneurs. The strategy is early identification and intentional development of entrepreneurial talent. This will compliment Kenya's new competency-based education, which focuses on learners demonstrating the knowledge and skills acquired. It is expected that the empowered young people will better contribute to job creation, a priority towards ultimately achieving Vision 2030[30] and the Big Four Agenda[31].

**Allan Gray Entrepreneurship Challenge (AGEC)**

AGEC is a new challenge in Kenya for aspiring high school entrepreneurs. The project was piloted for the first time in Kenya in 2019; known as #AGEC19_KE. The pilot tested if secondary/high school learners in Kenya would participate in an online Entrepreneurship Challenge. The challenge is a six weeks' competition using gamified learning, involving action-oriented micro-challenges aimed at developing the entrepreneurial minds of secondary/high school learners.

AGEC is open to learners, in any year of secondary/high school, with access to the internet. The learners take part in a web browser or mobile app-based game with a series of micro-challenges exposing learners to useful entrepreneurial mindsets and concepts that can be applied on a day-to-day basis; as summarized in **Figure 1**. A total of 36 challenges were developed and contextualized for secondary/high school learners in Kenya, with themes focused on Kenya's Big Four Agenda, and job creation towards achieving Vision 2030.

As also portrayed in **Figure 1**, AGEC is guided by five mindsets namely innovative thinking / intellectual imagination; personal initiative; resilience / grit; changemaker / spirit of significance; and drive / achievement excellence. The Entrepreneurship Challenge stimulates learners into thinking like entrepreneurs. Learners, teachers, and schools with the highest scores are awarded with weekly prizes, and top achievers recognized at the final celebrations (Allan & Gill Gray Philanthropy, 2019).

[30] Kenya Vision 2030 is the new long-term development blueprint / national planning strategy for the period 2008 to 2030 (Republic of Kenya, 2007). It "aims to transform Kenya into a newly industrialising middle-income country providing a high-quality life to all its citizens by the year 2030" (Republic of Kenya, 2007).

[31] Big Four Agenda is a directive by Kenya's President Uhuru Kenyatta to ensure that the people of Kenya meet their basic needs http://www.president.go.ke/. It is focused on (i) enhancing manufacturing; (ii) food security; (iii) universal health coverage; and (iv) affordable housing (The Presidency, 2018).

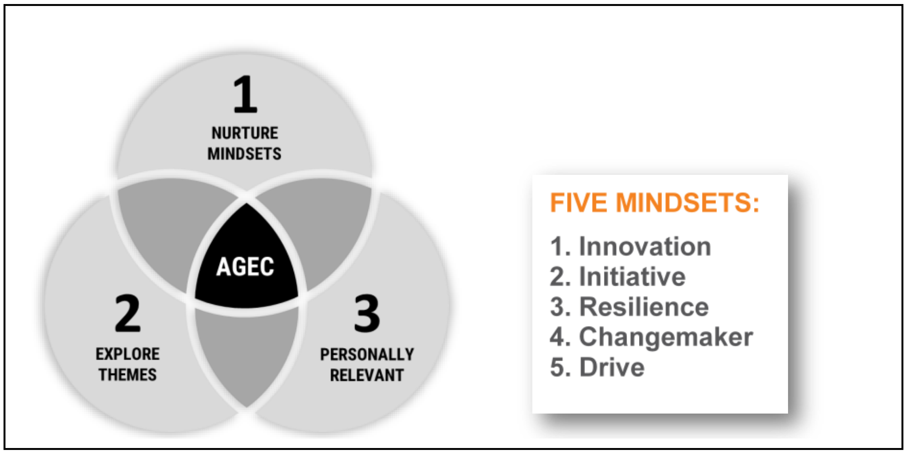


*Figure i: AGEC Challenge Design and Mindsets*

## Methodology

### Secured Partner Organizations

To start with, AGGP identified and partnered with organizations mandated by the Ministry of Education (MoE) to work with secondary/high schools; namely the Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA); Educate! Kenya; Kenya Association of International Schools (KAIS) and Kenya Private Schools Association (KPSA). These are professional organizations or associations working in the education space. These partners were referred to as AGEC partner organizations.

### Mobilization of schools to participate

AGEC partner organizations then approached their affiliated secondary/high schools and, with AGGP's support, informed them about the Entrepreneurship Challenge. Partners encouraged all their affiliated secondary/high schools, with computers and internet connectivity, to participate. The AGEC platform can accommodate many participating schools at a national level. Hence, all schools that confirmed willingness to participate were included in the pilot.

### Teacher training

Principals of each willing school then selected one or two teachers and approved their participating in a half-day workshop. A total of 130 teachers were trained in four regional trainings conducted in the Rift Valley, Coastal and Central Kenya. Further, 28 online webinars were conducted, before and during the Entrepreneurship Challenge. The webinars reached 358 teachers. These capacity enhancement sessions equipped educators on the Entrepreneurship Challenge platform, and on how to support learners.

### The Entrepreneurship Challenge

The challenge was run, during the Ministry of Education (MoE) Term II, from 22nd May to 3rd June 2019. Each week, a set of challenges were released that stimulated learners into thinking like entrepreneurs. Before the end of the week, learners uploaded their responses online. These were assessed, and weekly top achievers were rewarded, for instance with branded hoodies, backpacks, water bottles and Bluetooth speakers. The learner awards were mainly couriered and, were possible, delivered during school visits.

The survey was conducted during and after the Entrepreneurship Challenge. Data was extracted from the AGEC platform and analysed mainly utilizing MS Excel.

### Results and discussion

### Participating Schools

During #AGEC19_KE - the first ever online entrepreneurship challenge for secondary/high school learners in Kenya - a total of 141 schools participated. This number significantly surpassed the pilot target of 50 schools.

The secondary/high schools were both public and private, located in numerous counties across Kenya including Baringo, Bomet, Kajiado, Kericho, Kiambu, Kilifi, Kwale, Laikipia, Kisii, Machakos, Mombasa, Nairobi, Nakuru, Narok, Nyandarua, and Uasin Gishu.

These results confirm that piloting in collaboration with AGEC partner organizations was an important strategy that led to increased awareness of the Entrepreneurship Challenge, and hence the reach of many schools in Kenya. This is in line with the long-standing argument that partnerships are a tool for development with numerous advantages including transfer and creation of new knowledge and a conduit for influencing wider structures (Edwards, 1999).

### Learners engagement

A total of 2,154 learners were registered and participated in the online Entrepreneurship Challenge. Data showed that the number of participating learners ranged from as low as 3 to as high as 81 per school. The high engagement of learners in many schools was more than expected, but most welcome. It suggests that learners in Kenya have a highly competitive spirit and bravely engage in new opportunities and tasks. Furthermore, it demonstrates that learners have a high desire to develop their entrepreneurial thinking. According a report of the World Economic Forum, young people in Africa are well-endowed with entrepreneurial spirit and their early-stage entrepreneurial activity is 13% higher than the global average (Cann, 2019).

The highest percentage of the competitors were form two learners (31.8%), followed closely by form three (30.2%), 12.9% form four and 11.9% form one. This finding may suggest that educators opened the opportunity more to learners in form two and form three. The lower number of form four learners engaging in the challenge was expected, as examination candidates predominately focus on covering the syllabus, and sitting national examinations towards the end of the year

(Ministry of Education, 2018). This not only increases their chances of passing well, but also increases their chances of a good further education. Collectively, it contributes to achieving the national target of increasing transition rates to technical institutions and universities (Republic of Kenya, 2007).

As expected, initially there was low engagement in the challenge in the first couple of days, as shown in **Figure 2**. Data showed that learners completed more challenges in the second half of the term, as the competition intensified, and countdown of days begun.

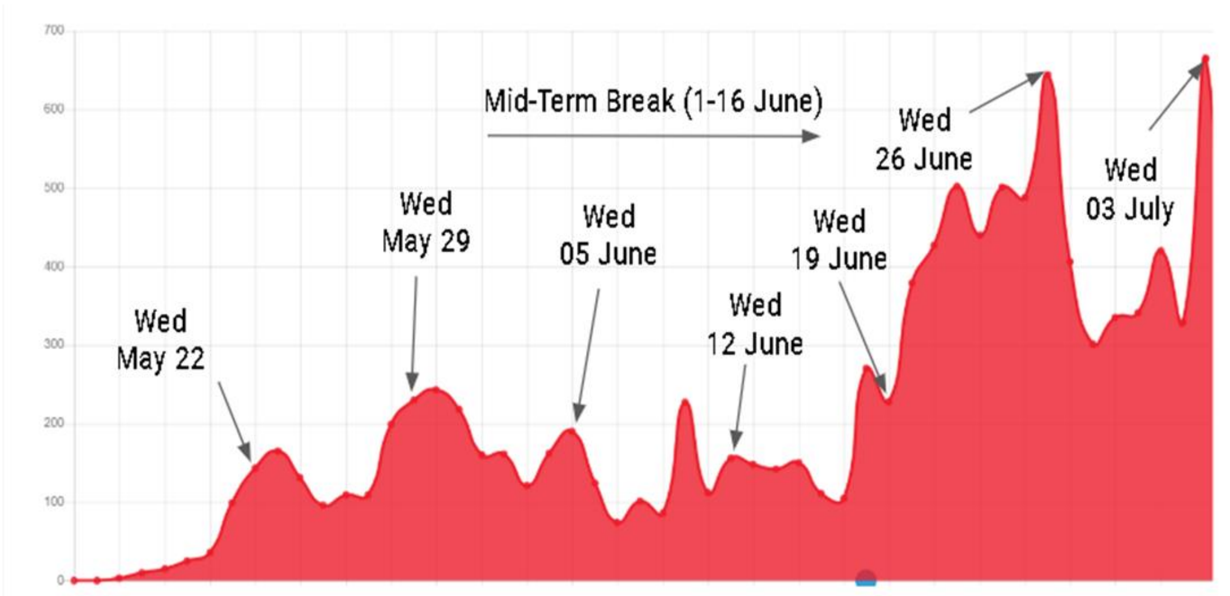


*Figure ii: Challenges completed*

**Learners' access to devices**

Contrary to earlier expectations, submissions declined during the mid-term break, as shown in **Figure 2**. This was an interesting finding that demonstrated that learners struggled with access to computers or mobile/cell phones with internet connectivity when they were at home.

Further analysis was conducted on when learners engaged in the challenge. As depicted in **Figure 3**, majority of the learners participated whilst they were at school. Data further showed that top performing learners - who completed many challenges – similarly participated during school.

These key finding suggests that learners - irrespective of whether they are in rural or urban schools, public or private schools, day or boarding schools - have better access to computers with internet connectivity whilst in school. As AGEC is an online challenge, it is crucial for learners to have computers with internet connectivity in order to participate and tap into the opportunities of thinking like an entrepreneur. In doing so, learners apply their 21st Century Skills and demonstrate what they can do including collaboration, creativity, innovation and problem solving. Further, in today's world, computers have become an essential part of learning as the use of technology increases active learning and interest, which in turn contributes to improved learning outcomes (Thuo, 2019; Muvango, Indoshi, Okwara, & Okoti, 2020). The more learners are engaged, the better they are at internalizing knowledge and applying skills gained. These are essential outcomes sought in the Competency Based Education (Ministry of Education, 2018).

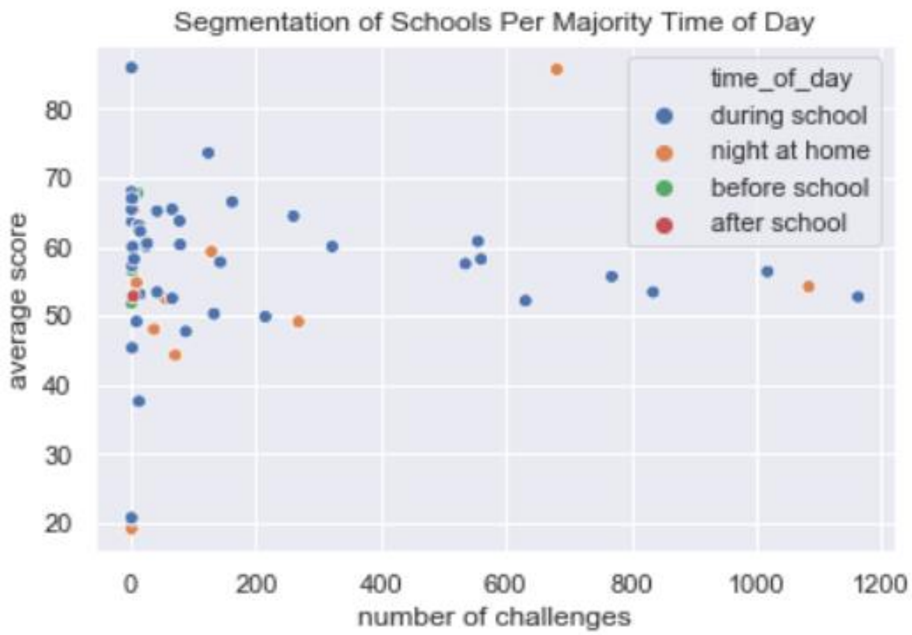


*Figure iii: Segmentation of schools per majority time of day*

## Effect of Teacher Training

We further analysed involvement per county in relation to the three teacher training sites. As depicted in **Figure 4**, counties situated close to where the teacher training sessions were held (in the Rift Valley, Coastal and Central Kenya) displayed greater participation as compared to others. The significance of this needs further analysis by examining the geographical concentration of secondary/high schools in Kenya. Nonetheless, the finding suggests that teacher training sessions are valuable activation tools that can help attract more participants in the counties.

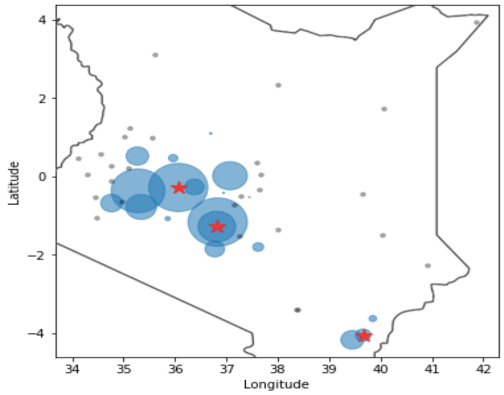


*Figure iv: Involvement per County in relation to the three teacher training sites*

## Effect of School Visits

During the challenge, AGEC and their partner organizations visited some schools, presented awards and motivated the learners. A visit was conducted at Menengai High School, Nakuru County, which resulted in learners' challenge submissions growing over 600% as indicated in **Figure 5**. This was a clear indication that school visits by the AGEC team was a key activation mechanism for the learners and schools at large.

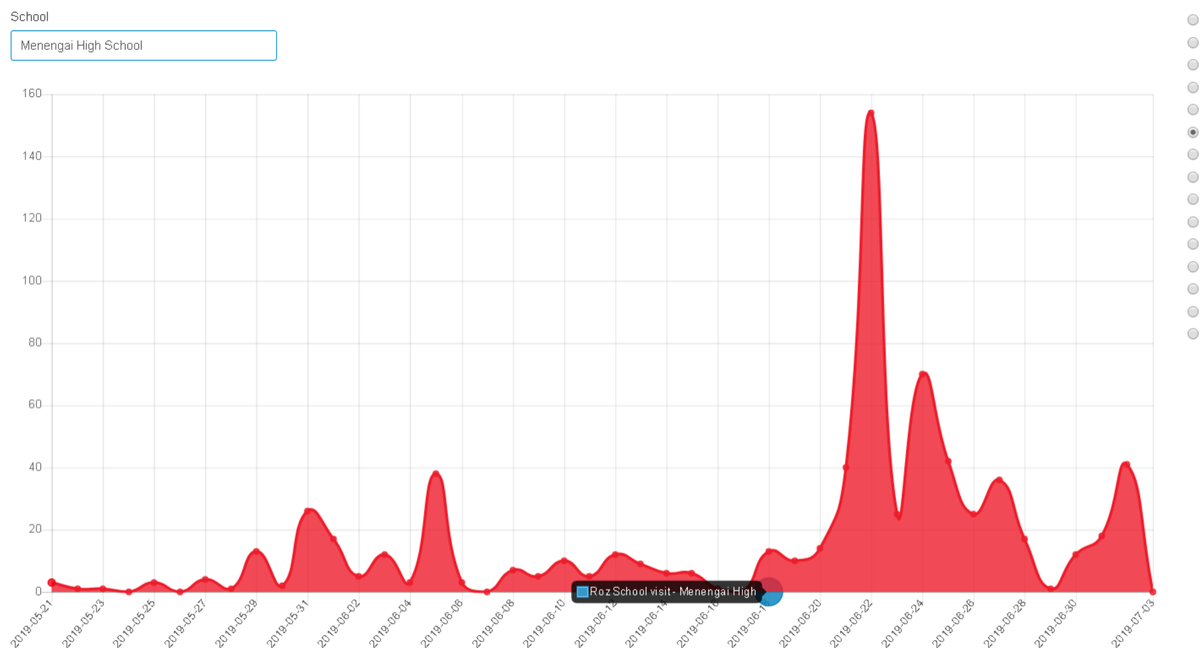


*Figure v: Menengai High School challenge submission analysis*

## Participation of AGEC Partner Organizations

Data was analysed to identify the top achievers. Recognition was made of the top learners, teachers, schools and counties[32]. It was encouraging to record that top performers were not only from private, but also from public schools.

We further examined the affiliation of winning schools. **Figure 6** shows that 57% of the schools were affiliated to KPSA, 28% CEMASTEA, 14% Educate! Kenya, and 1% ASANTE Africa. This suggested that the more active an AGEC partner organization was at activating and motivating school principals, teachers and therefore learners, the better their affiliated schools seemed to perform.

An encouraging observation was that a few learners participated through their own volition. However, none of them reached top achievement. This finding further highlights the importance of learners obtaining support from their teachers, principals, parents, family members or anyone in the community interested in nurturing learners.

[32] http://entrepreneurshipchallenge.africa/agec19_ke-grand-prize-winners/2019/08/08/

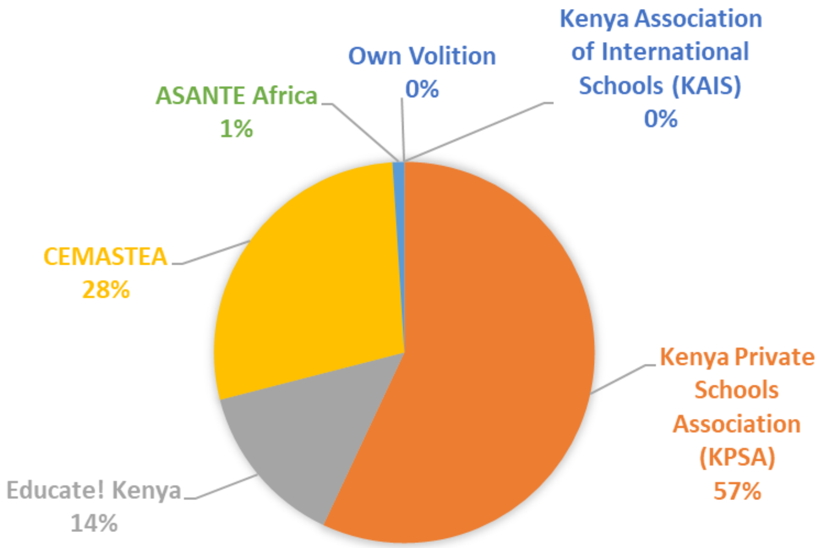


*Figure ix: Affiliation of winning secondary/high schools*

Overall, the findings show that the pilot implementation through AGEC partner organization was an important strategy, which resulted in reaching many schools, teachers and learners spread across numerous counties. It confirms that collaborating with partners is a strategic means of rapidly reaching and providing this entrepreneurial mindset development opportunity to stimulate entrepreneurial thinking of as many learners as possible throughout Kenya. Further, it puts into practice the Government of Kenya's strategy of strengthening partnerships to improve education and training (Republic of Kenya, 2007). As AGGP enhances the capacity of AGEC partner organizations, and in turn school principals and teachers, this will lead to active participation of the stakeholders in entrepreneurship education and training – an important component to ensuring sustainability (Galvao, Marques, Ferreira, & Braga, 2020).

## Recommendations

The focus of this pilot project was to test if secondary/high school learners in Kenya would participate in an online Entrepreneurship Challenge; literature had showed that such a crucial opportunity was not available. Several lessons emerged from the AGEC 2019 pilot project, from which recommendations are drawn.

Firstly, through working with partner organizations mandated to work with secondary/high schools, 141 schools participated; far exceeding the pilot target of 50 schools. Partnerships are indeed a strategic means of rapidly reaching and stimulating learners. Partnerships should continue, for, "*If you want to go fast, go alone. If you want to go far, go together.*"[33] Hence, it is

[33] African Proverb, Author unknown.

recommended that the scale up of AGEC in Kenya should be done in collaboration with partner organizations and other key stakeholders.

Secondly, there is a desire for entrepreneurial mindset development amongst learners. Learners with entrepreneurial spirit are in both public and private schools, boarding and day schools, and are spread across the country. Their entrepreneurial spirit is an asset which should not go unnoticed; rather it should be nurtured early.

Thirdly, learners generally have better access to devices whilst in school; with minimal or no access at home. Learners' ability to access devices is essential in e-Learning today, as well as in accessing opportunities like this online Entrepreneurship Challenge. This status has implications for policy makers and stakeholders. Questions to be addressed include: How can Kenya fast-track adequate access of computers for secondary/high school learners? In what ways can access points be expanded so that learners gain access to devices when they are at home?

Fourthly, it was noted that schools near areas where the teachers training sessions were held had high level of participation. It is, therefore, recommended that future teacher training sessions be conducted in various counties in the country to attract more interested parties to the competition.

Further, school visits by members of the AGEC team led to an increase in challenge submission. During the next challenge, AGGP and its AGEC partner organizations should plan for more school visits as it is a motivator and an activation mechanism for the schools, principals, teachers and more so the learners.

Finally, to reap tangible returns in future, policy makers and stakeholders need to fasttrack creating conducive environments that will intensify nurturing learners' entrerpeneurial spirit and/or innate talent at an early age.

**Conclusion**

AGGP is taking a step in changing the narrative and is contributing to stimulating and increasing the skill of secondary/high school learners, which will enable them develop an entrepreneurial mindset. This is a timely intervention that complements ongoing efforts to equip the young people with skills that will help them be entrepreneurs and job creators. Secondary/high school principals, teachers and learners, with the support of AGEC partner organizations and other stakeholders, should continue embracing this online Entrepreneurship Challenge and scale up efforts to equip young people with relevant skills to create future entrepreneurs.

**Acknowledgement**

Our profound gratitude goes to the 2019 AGEC partner organizations without whom this work would not have been a success. Thank you to CEMASTEA, Educate! Kenya, KPSA and KAIS for journeying with us during the pilot project.

This work was supported by AGGP. Our deepest appreciation goes to the Gray Family for their long-term commitment to motivating and supporting individuals in Africa to become high-impact, responsible entrepreneurs.

Further we thank Anthony Farr, CEO AGGP, as well as all members of the AGEC team in 2019 namely Chris Campbell, Anthony Selley, Rekgotswe Wagaiyu, among others for their dedicated efforts, and Faith Kaburi and Amanda Luyenge for their administrative support.

Finally, we thank the anonymous reviewers. Your useful suggestions have contributed to improving the quality of this paper.

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**Strand 3 # School Culture and Learning in STEM**

1. Leadership for Learning: Case Studies on Support and Supervision
2. Creating Space for in / out of school STEM Learning and application
3. Equity and Access in STEM Education
   a. Gender-based STEM Education
   b. Inclusive STEM Education for Learners with Special Needs
   c. Increasing STEM Learning Outcomes for Vulnerable Children

**Article 19**

# Women in leadership, gender bias in ICT leadership in Botswana's schools-The case of the central region

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**Abstract**

The ICT sector of STEM is growing rapidly the world over and this growth has led to the demand for skilled personnel. However, figures indicate a bias against women in ICT globally. For example, in South Africa 26% of the Technology workforce are female. Canada and Austria have 26.7% and 28% respectively. The purpose of this study is therefore to determine if these trends prevail in Botswana with a specific focus in the Education sector. The research was carried out through a statistical analysis of 81 secondary schools in the Central Region to find out how many of these schools have women leading the ICT departments. The study seeks to identify factors leading to gender imbalances in ICT leadership in the schools. The statistics showed that only 22 of the 81 schools had women heading the IT department. These findings showed that gender inequalities in ICT emanate from the processes of recruitment, retention and the advancement of women in this sector. The study recommends that polices of affirmative action be put in place so as to promote women in ICT within Botswana's education sector.

**Keywords:** *Gender bias, women in technology, leadership in ICT, inclusive policy*

**Abbreviations:** *EU-European Union, ICT-Information and communications Technology, IT-Information Technology, STEM-Science Technology Engineering and Maths, STI-Science, technology and innovation, UN-United Nations, UNESCO-United Nations Educational, Scientific and Cultural Organization, USAID-United States Agency for International Development*

## Introduction

Biases and gender stereotypes that have existed for a long time, contribute to driving girls and women away from science related fields. In an endeavour to create opportunity for full and equal access to and participation in science for women and girls, the United Nations General Assembly adopted resolution A/RES/70/212 declaring 11 February as the International Day of Women and Girls in Science in December 2015. Four years later, the difference is still minimal but evident as noted in the message given on this day in 2019.

"We are determined to encourage a new generation of women and girl scientists, to tackle major challenges of our time. Heeding the call of Greta Thunberg, young women scientists are already making a difference in the fight against climate change, including South-African teenager Kiara Nirghin whose inventions minimize the impact of droughts. By harnessing the creativity and innovation of all women and girls in science, and properly investing in inclusive STEM education, research and development and STI ecosystems, we have an unprecedented opportunity to leverage the potential of the Fourth Industrial Revolution to benefit society."— Joint-Message from Audrey Azoulay, Director-General of UNESCO and Ms Phumzile Mlambo-Ngcuka, Under-Secretary-General and Executive Director of United Nations Women on the occasion of the International Day for Women and Girls in Science 2019.

In spite of such efforts as made by the UN, the gender gap in ICT is not being closed. According to Eurostat in April 2018, there are still low numbers of girls and women in ICT learning. The report draws attention to the fact that in 2016, there were more than 1.3 million people enrolled in ICT courses in the EU and only 16.7% of those were female. An interesting point to note is how some countries have much higher female representation in ICT courses than others, "across the EU Member States, the share of female students ranged from less than one-tenth in the Netherlands (6%), Belgium (8%) and Luxembourg (almost 10%) to over a quarter in Bulgaria (33%), Romania (31%), Greece and Sweden (both 29%) as well as Cyprus (26%)." This phenomenon is not unique to the EU nor the United States only, it is even more so on the African continent.

The Central region is the largest educational region in Botswana (Southern Africa), comprising of eight sub regions and 81 secondary schools. The other nine regions share the county's remaining 200 schools among themselves with an average of 22 schools per region. Each of these schools has an ICT department with a maximum of two people in the junior and up to five in the senior secondary schools. Botswana primary's schools do not have personnel specifically for ICT. The Maths and Science teacher is expected to oversee activities that include ICT use and infusion. And if the person is not inclined towards the area, then it will be neglected to the detriment of the entire school. The exception is the Kgalagadi Region whose primary schools have IT officers with the help of the Botswana Communications Regulatory Authority and USAID.

**Key concepts**

**a) Gender**

Gender is the range of characteristics pertaining to, and differentiating between, masculinity and femininity. A majority of societies have a construct that refers to two types, boys/men and girls/women guided mostly by the biological characteristics of male and female. This construct refers to the social and cultural constructs that each society assigns to behaviors, characteristics and values attributed to men and women (Wikipedia). The basis of the construct lies behind the idea that they are natural or intrinsic, and therefore, unalterable. These gender constructs are shaped by ideological, historical, religious, ethnic, economic and cultural determinants. These are usually translated into social, economic and political inequalities, where men's activities and their gender attributes are perceived as essentially superior to women's, resulting in unequal treatment in employment opportunities such as promotion, pay, benefits and privileges.

**b) Gender Bias**

The term, according to the Free Dictionary by Farlex, refers to "unequal treatment in employment opportunity (such as promotion, pay, benefits and privileges), and expectations due to attitudes based on the sex of an employee or group of employees''. Gender bias can be a legitimate basis for a lawsuit under anti-discrimination statutes. Okunna (2000) stresses that gender relations are characterized by a lot of imbalance, to the disadvantage of women, by keeping women in subordinate positions to their men counterparts. Gender attributions are therefore often justified on the basis of sexual or biological differences. For instance, women are perceived to be "naturally" nurturing, a characteristic linked to their reproductive capacity as child bearers. This gender attribution is dominant in the field of science and technology the world over. This is because this field is often categorized as "hard" and therefore "masculine", a field traditionally considered unsuitable women. For instance, the notion that women perform poorly in science and technology in comparison to men is often attributed to biological limitations of women, rather than to gender stereotypes in educational materials, teaching approaches, study opportunities and technological designs that contribute to the gender gap in ICT use. Over the past 15 years, the global community has made a lot of effort in inspiring and engaging women and girls in science. The concern is that they are still under-represented in STEM related fields while they represent more than half the population in Africa. Recent studies revealed that gender disparities still persist, reiterating the need to ensure quality education for girls in order to help them perform well (Smith, 2008).

**c) Women in leadership**

In past times, power has been distributed among the sexes disparately. Power and powerful positions have most often been associated with men as opposed to women. As gender equality increases, women hold more and more powerful positions, due to policy and social reforms, but in the science and technology field this change is not remarkable at all, even though accurate and proportional representation of women in social systems has been shown to be important to long-lasting success. Additionally, some studies show that "absence is not merely a sign of disadvantage and disenfranchisement, but the exclusion of women from positions of power also compounds gender stereotypes and retards the pace of equalization" (Reynolds, 1999).

Gender should not be a basis in determining whether or not a person can be a great leader. Leadership abilities should depend on an individual's strengths and personality traits. However, in many cases, women aren't encouraged to take on leadership roles as often as their male counterparts, contributing to an imbalance in leadership. But, the inclination that women possess for a holistic, self-reflective approach may be an explanation of why female employees define leadership differently than some men do. Sixty-five percent of women (versus 56 percent of men) said they view leaders as those who share their knowledge and connect with their colleagues to help the team and the business. When women bring this attitude into managerial roles, it may actually make them stronger, more-effective leaders. Women may not always realize how poised for success they are in leadership roles, but their potential and abilities are undeniable. Business News Daily asked female leaders to share their thoughts on women in power. Some of the reasons they gave as to why women make the best leaders include: the value for work-life balance, a sense of empathy, focus on teamwork, great skill at multitasking and the ability to check their egos among other things. (Original Source: Business News Daily)

### Objective of the research

- Determine the extent of gender bias if any in the leadership of ICT in the Central Region (Botswana)

### Why the study

Most studies usually provide a base for further research by other researchers. The findings of this study therefore must cultivate and inspire ideas in curriculum developers and syllabus designers in Botswana so that they come up with measures that retain and grow the participation of the female in the male dominated ICT sector in schools. The study will definitely help policy makers in education to understand the actual position of women in leadership of ICT; as a result, policies should be devised to facilitate the narrowing of the gender gap. It will also unveil new areas of interest and in that way, it will prove useful for more researchers to look further and explore other dimensions in relation to information and communication technology and gender.

### Methodology

The Central region is the largest educational region in Botswana as such it was appropriate as it represents 28% of the sample population (81 schools out of a total of 280 countrywide). Data was collected by calling all the 81 schools in the region and requesting the information from management. As the researcher is also a Senior Teacher I in ICT, social interactive platforms common to this IT fraternity were also used to corroborate the data collected telephonically. The interactions on both WhatsApp and Facebook proved to be very fruitful as many of those on the ground responded to the request by the researcher to provide the number of females in their departments. Needless to say, the responses sparked interesting debates on what could be the possible reasons for the differences. On completion of the data collection, the data was analysed quantitatively and presented using a table and percentages.

## Results

The results of the survey indicated that in all the sub regions while there were areas that did not have substantive ICT officers, a majority of the offices were held by males (Table 1).

***Table 1:*** **Gender Inequality in Schools in the Central Region (Botswana)**

| **AREA** | **% male** | **% female** | **%vacant** |
|---|---|---|---|
| Boteti Sub Region | 88 | 12 | 0 |
| Bobirwa Sub Region | 70 | 21 | 9 |
| Palapye Sub Region | 73 | 13 | 14 |
| Mahalapye Sub Region | 90 | 6 | 4 |
| Tonota Sub Region | 86 | 12 | 2 |
| Selibi Phikwe Sub Region | 66 | 34 | 0 |
| Serowe Sub Region | 54 | 42 | 4 |
| Tutume Sub Region | 64 | 17 | 19 |

## Discussions

Studies show that in general, including this one, women are under-represented in ICT professions and education. One of the factors responsible for the status quo is the fact that women identify job security and flexibility of working hours as a motivator while men are attracted and motivated by technology and advancement in the ICT sector, in this manner the time and energy necessary to make an impact in the tech world deters many women. As primary home builders the long hours do not necessarily fit in to the schedule of a career. Other studies also show that in schools, female students are less satisfied with the introduction of computers in learning than their male counterparts are although they perform better in areas where presentation and verbal skills are applied. Therefore, the fact that the Serowe Sub Region has a high number of women in ICT leadership is to be recognised. Though as a country Botswana does not have special dispensation towards women to further enhance their visibility especially in leadership in their chosen field.

## Conclusion

The researcher appreciates that girls' and boys' cultural or social orientation play a role in their career decision making. But in the same way that one un-learns certain practices, so it should be with traditional gender roles. These orientations set expectations and rules for how people should behave solely based on their gender, when in reality, people should be able to choose who and what they want to be. It is therefore imperative that women in technology realise that gender roles are fluid. They must not always conform to practices that contribute towards marginalisation. In addition, ICT opportunities for women and girls should provide enough chances and result in environments that support economic empowerment. Women should be empowered to change their attitudes that create a barrier to ICT use for them. The research therefore recommends that, it is important for policy makers to come up with a policy which supports women use of ICTs and a fair distribution of ICT jobs between men and women. "In contrast to men, who tend to be career-centric and want to maximize their financial return from work, women view work more holistically, as a component of their overall life plan," Emily He, former chief marketing officer at Saba. "Therefore, they're more likely to approach their careers in a self-reflective way and value factors such as meaning, purpose, connection with co-workers and work-life integration. Such observations should drive society towards being more accepting of women in leadership in science and technology too,

## Acknowledgements

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**Article 20**

# Is Botswana education system inclusive of learners with special educational needs? A case study of four junior secondary schools

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**Abstract**

According to the guidelines of the United Nations Educational Scientific and Cultural Organisation (UNESCO), inclusive education is the process of addressing and responding to the diversity of needs of all learners through increasing participation in learning. The inclusion model or movement stresses that a child with a disability be placed in the same education environment he or she would otherwise have been placed in if it were not for the disability. Most provisions for children with special educational needs include the development of structures and availability of appropriate learning tools for particular categories of disability attached to ordinary schools. The question now is; do we see these policies being effectively implemented in schools? Are our school environments in accord for equity and accessibility for children with special needs? The study therefore seeks to assess four Junior Secondary Schools in the Palapye and Serowe Sub Region in Botswana and gauge the availability of appropriate special needs provisions for varied cases. Qualitative methods will be used to verify the availability of provisions for special needs learners. A variety of sources including policy documents, literature, statistical data and interviews with key personnel and observations will be used to analyse the context and provision for special needs.

**Keywords**: *Inclusive education, special educational needs, educational policy*.

**List of Abbreviations:** *UNESCO – United Nations Educational Scientific and Cultural organisations, STEM – Science, Technology, Engineering and Mathematics, ADD – Attention Deficit Disorder*

## Introduction

The demand for social justice in the education sector, particularly in relation to children with disabilities has gained impetus in the world, especially over the latter half of this century. Previously, in Botswana as was the case with many African countries, children with disabilities were denied opportunities to attend normal schools. (Botswana Government, 1977) However, in the last few decades, the world has experienced the emergence of a human rights movement whose objective is to lobby states to guarantee the fundamental rights and freedoms of persons with disabilities. One of the themes that emanated from this movement is the protection and promotion of the right of children with disabilities to receive education (UNESCO, 2009). Thus, in the intervening years, there has been a remarkable paradigm shift from excluding children with disabilities from education to their inclusion (Fredericks., 2007). Today, more and more learners with special needs are studying under one roof, side by side with their peers who do not suffer from any disabilities. This concept is commonly referred to as inclusive education.

Botswana has committed to providing education for all through its Vision 2016 Agenda and beyond. Although significant progress made in this regard, this has yet to be accomplished. It is now committed to extending and developing education in Botswana through an inclusive education approach so that Education for All becomes a genuine reality (Botswana Government, 1977). The need for such a policy is based on the Government's commitment to human and educational rights and on the country's need to maximize the full potential of its population to take its place in the modern world. Botswana, with its comparatively small population needs all the educated and skilled citizens that the education system can produce. However, despite the fact that inclusive education has gained immeasurable currency in modern pedagogy, Botswana has not done enough to cater for the education needs of and address challenges faced by children with disabilities as well as those with special needs.

## Literature review

According to (Forlin., 2004) Inclusive education is about looking at the ways our schools, classrooms, programs and lessons are designed so that all children can participate and learn. Inclusion is also about finding different ways of teaching so that classrooms actively involve all children. It also means finding ways to develop friendships, relationships and mutual respect between all children, and between children and teachers in the school. (Forlin., 2004)

Inclusive education means that all children are educated in regular classrooms. It does not, however, mean that individual children cannot leave the classroom for specific reasons. For example, a child may require one-on-one assistance in a particular subject (Jennifer., 2012). This may or may not be happening during regular class time. Once schools are inclusive, serious thought is given to how often a child may be out of regular classroom and the reasons that this may be happening It does not mean that children with certain characteristics (for example, those who have disabilities) are grouped together in separate classrooms for all or part of the school day (Haddad, 2009).

According to (Rouse, 2008) Inclusive education means students with diverse and different learning and physical abilities staying in the same classroom to learn side by side. (Rouse, 2008) Further argue that it is the act of placing students in age-appropriate general education classes in schools available in their immediate environment that gives access to high-quality instructions, interventions and assistance to meet up primary and secondary academic curriculum irrespective of any challenges they may have. Educators need to recognise the fact that children with disabilities have equal capacities to learn and perform optimally as their age-mates that are without limitations (Farrell, 2000). These children are therefore supposed to be part of all educational activities in their classrooms and within the neighbourhood. Such activities include excursions, academic debates, student government, sports and other related activities (Farrell, 2000).

**Importance of inclusive education**

**Healthy Friendship development**

Other than academic education and learning made available to children in school, friendships are developed, and social skills learnt. Allowing special needs children to mix with other children in the school setting makes them feel included, and this expands their network of friends (Odom, 2011).

**Development of a positive perception of themselves and others**

(Tahir., 2010) Suggests that attending classroom settings that depict the true nature of the similarities and differences that exist in the world helps children appreciate diversity. It is essential that a child's education introduces him/her to the reality of the world out there beyond the walls of just an academic environment. Playing and learning alongside with other children of different cultures and abilities assist children to grow in understanding people that are unique in skills due to physical, social or other challenges. The culture of respect for one another also grows when children are allowed to play with one another without segregation. (Tahir., 2010)

**Realization of parent's dreams**

On the other hand, (Florian., 1998) every parent wants their child to be happy and accepted by their peers, have a healthy life and education. Allowing a child with the special need to interact and learn with other students in the school positively improves their academic performance, their personality and the expectations of the parents. According to (Florian., 1998) introducing inclusive education in the classroom will reduce stigmatisation and help such children attain their highest heights.

**Parental Involvement in Education**

Introducing Inclusive education into the classroom encourages parents to be actively involved in their child's education and other school activities. Parents love to witness the performance of their children during events such as debate, quiz competition, sports and other programs. It also drives a higher commitment to the school by the parents as they become more involved in the school program (Jennifer., 2012).

**A broader range of learning methods**

An Inclusive education system makes teachers and staff flexible when it comes to preparing their teaching and instructional materials. The use of non-traditional resources like videos, audio, kinaesthetic and even multimedia can be employed to make learning more accessible and exciting. By doing this, even students without disabilities learn faster too (Haddad, 2009).

**Better academic performance**

Research has shown that students learning together in the classroom improves academic excellence. Students set higher expectations for themselves due to the presence of others with diverse abilities. Students with disabilities challenge themselves to perform optimally like their classmates, while other students also spontaneously set a high standard for themselves. As educators, we won't know what gifts are hidden in our students until we unwrap them (Rouse, 2008).

**Development of leadership skills**

Students in an inclusive education environment naturally learn to take up the responsibility of caring for one another. (Florian., 1998) Opine that there are situations where students stand up and speak up to protect their friends who are bullied. This naturally can lead to a leadership skill. The school environment also encourages self-discovery as students with diverse abilities find themselves performing roles and functions they usually would not be exposed to if they had been separated.

(Farrell, 2000) Suggests that to fully implement inclusive learning in the classroom there should be a development of a culture of acceptance, understanding and giving equal attention to the diversities and differences of all the students in the school. Here are some of the essential elements that characterise inclusive education;

**The use of a broader range of instructional materials, teaching aids and models:**

The purpose of contemporary tools such as interactive whiteboards, videos, audio lessons and multimedia tools are often associated with higher student engagement. A lot of times, teachers also employ the use of groupings to carry out academic exercise in the classroom. Often the groups are shuffled just to allow all students to relate to each other and carry out the task assigned to them. Teachers lead group task in the cases of younger age students (preschool or elementary) or driven by a student when dealing with older children (Secondary school)

**Inclusive academic curriculum**

The same learning goals drive the learning experience of every student. The content of the school academic program is such that gives equal opportunity for all the students to participate in all school educational activities at the same pace of progress. Educators consider students with disabilities before creating the school curriculum. They do this to allow all students to have equal access to instructions and opportunities to participate in learning activities. Such curriculum makes provision for students with special needs to be given attention without pulling them out in the middle of lessons and making their differences noticed.

## Disadvantages of inclusive education

When we talk about changing the regular school, there should not be omitted inevitable changes in: the architecture of the schools and the removal of the architectural barriers for save moving of the pupils; providing appropriate material - technical means and equipment for the pupils hiring a larger number of experts, specialists in working with children with special needs; adequate and continuous training of teachers for work with children with special needs, because so far the very initial teacher education was aimed at upbringing and education for the regular pupils, but not for the children with special educational needs (Rouse, 2008). Therefore, these teachers need basic knowledge in this area, and then a continuous enhancement of that knowledge; raising the community awareness of human differences and respecting those differences, which in turn will help the accepting of the children with special needs in regular classes by the other children and their parents

## Mainstream classrooms aren't always an appropriate fit for students with disabilities

(Odom, 2011) Observes that mainstream classrooms may not be an appropriate fit for students with disabilities because the other children may not know how to deal well with their differences.

## Disabilities

Children with learning disabilities can also sometimes be disruptive in class. These disabilities can be classified anywhere from attention deficit disorder (ADD) to autism and dyslexia. In most cases, students with learning issues require a specialized education plan to teach to their needs. Many students with learning disabilities are on medication that helps them focus. Occasionally, students forget their medicine and act out in class on those days.

Those who are against inclusion, especially the model of the full inclusion regular education is not ready for inclusion. To have a successful inclusion it is necessary to a large extent to be changed and adjust the environment in the regular teaching as well as attitudes towards children with special needs that must be accommodated in quite the opposite environment. According to these authors, these pupils benefit more if at least part of their school day will be spend out of the regular grade (Haddad, 2009).

## Methodology

## Introduction

Methodologies are strategies, pedagogies used to gather information in a study.

Quantitative method of data collection will be used to collect relevant data for the study. Martens (2005) argue that interpretative researcher is mostly likely to rely on qualitative data collection methods and analysis or a combination of qualitative and quantitative methods.

Quantitative research is alarmed to explain phenomena by collecting numerical data that are analysed using statistical tools and methods. Questionnaires were used as a quantitative method to collect data. The main aim of using it was to find the out whether Botswana educational policy is inclusive of children with disability.

The reason why the researcher opted for this method as method of data collection was that the researcher believes that the area under discussion can be investigated quantitatively because the intention was not to seek in-depth information or discover more implications but to gather piece of information to explain the existing situation.

Qualitative method also as an opted method, Interview was conducted. Berg (2004) defined qualitative research as any kind of research that produces findings not arrived at by means of statistical procedures. Words were used to describe them. Observations were also used to allow the researcher to observe the methodologies employed during content delivery during lessons. Like it is mentioned above that observations were used to get information on the impact of class size on students' outcomes and the methods applied during teaching. According to Elo & Kyngas (2008) data collected through qualitative method is rich with niceties and insights into participants' experience of the world and therefore become more meaningful.

The research was conducted in four selected secondary schools, in rural area, semi urban and urban area. These schools are selected for their accessibility to the researcher and also to cater for all four types of environment.

**Population of study**

The study comprised of the teachers, school management Teachers and management representatives were selected from the different geographical locations. Teachers are the ones that have experience in teaching students, so they are the main target in this study to help the researcher to get the required information that can prove if the hypothesis claim is true or not.

**Sampling Procedure**

Even though there are different ways in which participants can be selected, for this study purposive sampling was used. This is the chosen method because the main goal of the study is to develop a rich understanding Teachers were selected from all subject The aspect of gender was be taken into consideration to avoid bias since it is assumed that male and female teachers think differently about their work. The teachers will be selected using purposive sampling technique since the researcher intended to focus on teachers who understand the study well. This technique allowed the researcher to include only relevant people in the study. In a school two (2) representatives from languages, sciences and optional subjects were selected.

**Data collection instruments**

Since data was collected from different stakeholders the questions slightly differed thus accommodating the level of their understanding in line with the matter. For the teacher's questionnaire and interview questions were prepared for them to answer. When it comes to the school management, the form was designed such that it tracked the performance of students who wrote their junior certificate ten years from now. It is expected that the mixture of different data compilation methods within this study result in a deeply investigation of the phenomena being studied. Optional questionnaire was used by the researcher to collect data for the study.

**Validity and reliability of instruments**

Validity of both methods differs, qualitative data can be achieved through honesty, strength, wealth and extent of the data achieved. Validity and reliability are the key aspects and they are more common to qualitative study.

**Data collection procedures**

It is not polite to get into the institution to their surprise asked them questions. The researcher to be free to conduct interview and give participants' questionnaire the researcher obtained a research permit from the school head from the institutions to conduct a study. To avoid overspending and waste of time travelling, the researcher called the school heads for permission. Participants like teachers will be contacted also to make appointments for interviews.

During data collection questionnaires were administered to respective schools and observations made. While interview is on progress, the researcher will give other teachers questionnaire to answer also considering teaching subjects and give the Head of Department the result form to fill.

After the data is collected from all the above mentioned schools it will be jointed ready for analysis.

**Data analysis and processing**

Data collected using questionnaire was analysed using statistical analysis method. Graphs, tables and pie charts will be used to analyse data. Numbers and percentages will be used to explain the relationship between class size and students achievement. For the data collected through interview, content analysis will be used to scrutinize and understand interviews. Data will be evaluated and classified into reasonable thematic categories based on objectives. Analysis of data collected using interviews was an ongoing process where rising themes will be categorised based on the research. Categorised and oblique data summarised and new recognized variables described and analysed using tables. Finally, conclusions were drawn based on analysed data leading to recommendations and suggestions for further improvement of the impact of class size on student's achievement in Botswana junior Secondary schools.

**Ethical consideration**

The researcher sort approval of participants in the study. The information obtained from the participants will be respected because data will be realised to the public and other scholars with their knowledge and efforts. This is supported by Anderson and Boden (2008) that "the principle of informed consent arises from the subject's right to freedom and self-determination. Being free is a condition of living in a democracy and when restrictions and limitations are placed on that freedom they must be justified and consented to.

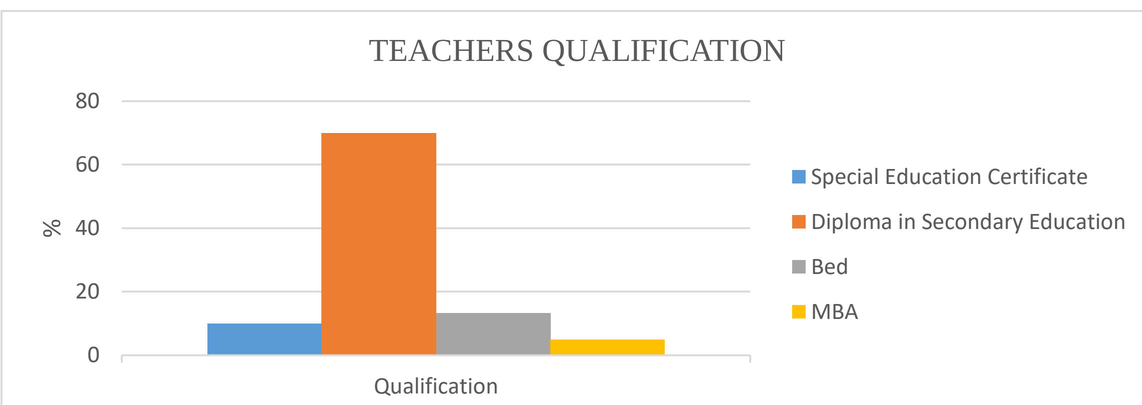
As the study aims to use people to investigate the impact of high class size and high student-teacher ratio on academic performance, there is a need to ensure privacy and security of participants. To ensure for the participant's privacy the researcher allowed them to remain anonymous in their answer sheets.

In the process of the study, cognizance was considered by the fact that this study investigated the magnitude of inclusive education and equity in ordinary schools. Participants were informed about the nature of the study. They will be given the option to participate in the study or not to participate, and also the option to opt out at any time of they feel they cannot continue with the study. Hence the researcher ensured that participants knew that their involvement in the study is voluntary at all times, (Anderson and Boden, 2008). Participants were given the consent form to sign as proof that they have accepted to participate in the study. They were also informed and assured that the information they provided shall be treated as confidential. In order to get to access to research sites, the researcher built a rapport with all stakeholders in the institutions involved in the research.

**Data presentation and analysis**

This chapter analyses data of the study conducted to find whether Botswana education system is inclusive of learners with special educational needs, the participants were all teachers with basics in special Education. However, only 5% of them have a certificate in special education.

**Fig 1.1**




The bar graph above reflects that most teachers are well trained for their jobs but only, that is, 3/30 which is 10% of those who Special Education Certificate, 21/30 which 70% of those who have Diploma in Secondary Education, 4/30 which is 13.3% of those who have Bed and 2/30 which is 6.7% of those who have MBA.

Research revealed that there are strong policies in Botswana education system which dictates that all children be allowed to the ordinary schools and that inclusive education be a norm. However, though the policies are good implementation is lacking, a lot need to be done to achieve the intended goals. During lesson observations it was realised that teachers when delivering content, they do not vary teaching techniques thus excluding those with special needs, lecture method dominated the schools.

**Fig 1.2**

| TEACHING METHODS | FREQUENCY |
|---|---|
| Group discussion | 2 |
| Pair work | 1 |
| Work sheet | 3 |
| Lecture Method | 24 |

The table above shows that 2/30 which is 6.7% that group discussion was used, 1/30 which is 3.3% that pair work was used, 3/30 which is 10% that work sheet was used and 24/30 which is 80% that lecture method was used. This reflected that lecture method was mostly used by teachers which excluded students with special needs.

Though policies support inclusive education, the school infrastructure are not accessible for children with disabilities. School infrastructure does not have ramps to allow wheel chairs to be used and the students' rest rooms only and the school at large cater for the so called 'normal' individual. In this regard equity in the classrooms and school environment is questionable and compromised.

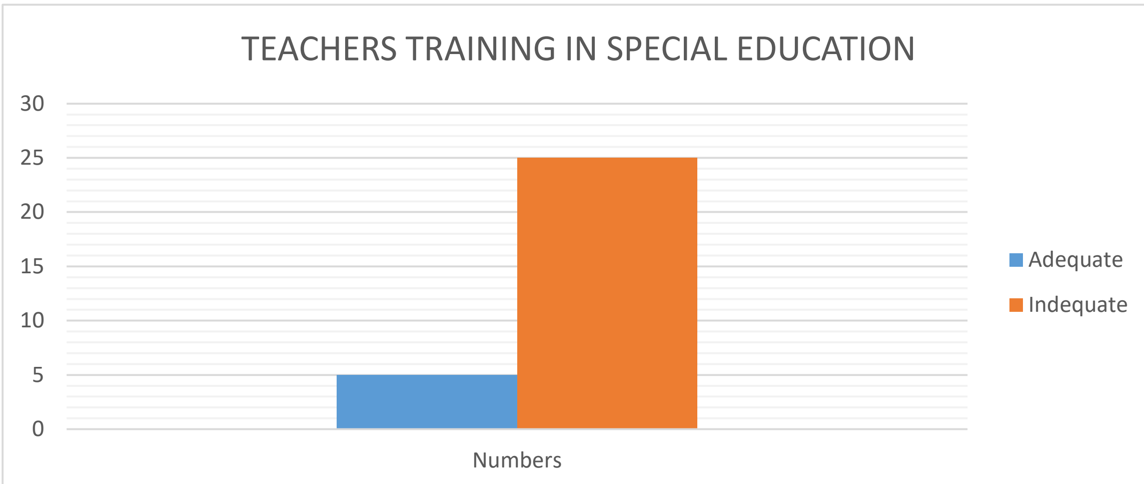
**Fig 1.3**

| INFRASTRUCTURE | NUMBERS |
|---|---|
| Ramps | 0 |
| Slope | 0 |
| Specialised Classrooms | 0 |
| Toilets | 0 |

The table above depicts that the infrastructure in most government schools is not accessible for students with disabilities which will make it difficult for this students to effectively learn. In addition, the rest rooms only cater for the so called 'normal'. This suggest that equity and accessibility is compromised thus defeating inclusive education.

The study also established that teachers' preparedness in terms of training, STEM learning and experience posed a great challenge to inclusive education implementation. According to the study findings most teachers agreed to the fact that their professional training was inadequate to take charge and impart knowledge and skills to pupils with special needs in education. They embraced to undertake specialised further training in special needs so that they can be professionally prepared to handle such learners.

**Fig 1.4**




The bar graph above shows that most teachers, 25/30 which is 83.3% received inadequate training which could be helping them in the preparedness for helping students with special needs. Only 5/30 which is 16.7% received adequate training in special education and it helps them in preparedness in helping students with special needs.

**Conclusion**

The concept of inclusion in education does not confine merely to classroom walls or school compound but it brings about changes in the attitude of children and adults towards their life in general. It is every child's right to be supported by their parents, teachers and the community to develop a positive understanding of themselves and others, regardless of their differences and abilities.

On the basis of the results of the study, it is concluded that despite all challenges, mainstream school teachers have a positive and favourable attitude towards inclusive of children with disability, they are ready to be part of such interventions provided all the prerequisites for introducing inclusive education are ensured. There is a need to adjust infrastructure in public schools to accommodate learners with disability and STEM learning. There is a relationship with literature and the results, that is, literature dictates that all learners with special needs should not be from others in the classrooms and this is what the Botswana education system have embraced in ordinary schools.

However, there is a need to adjust infrastructure in public schools to accommodate learners with disability and STEM learning, as research revealed that there are no specialised rooms, science laboratories, computer labs and Business Labs are also designed only to cater for the 'normal'. In addition to this, the results revealed that lecture methodologies dominate in government schools, and learners with special needs are referred to as 'slow learners' by many teachers. This actually defeat the goals of inclusive education as well as equity and accessibility in ordinary schools.

**Recommendations**

Public schools experience challenges which are thorny issue to inclusive education. The following are recommendations

1. The government need to make sure school infrastructure and resources are availed to schools so that they efficiently and effectively.
2. Strengthening of supervisor in school to make sure that teachers employ relevant pedagogies to in an effort to assist learners with disabilities.
3. Parents and the community need to be educated on inclusive education by working hand in hand with school

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**Article 21**

# Influence of politicism on institutional leadership in public secondary schools in Kajiado county, Kenya

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**Abstract**

This study focused on investigating the influence of politicism on institutional leadership in public secondary schools in Kajiado County. There is a strong connection between the public secondary schools and politicians because politicians provide financial assistance, bursaries and donations to schools. The sample size involved 5 education officers, 25 principals, 25 deputy principals and 185 secondary school teachers. The study employed the simple random sampling techniques for the selection of respondents and the stratified sampling techniques to select the various public secondary schools. Questionnaires, interview guides and document analysis checklist were used for data collection. Quantitative data was analyzed descriptively and inferentially while qualitative data was analyzed thematically. The study revealed that politics and education thrive in a symbiotic relationship. The study concludes that politics makes positive and negative contributions towards the education sector. The study recommended that public secondary schools should be completely free from political interferences though contributions of politicians towards the education sector should also not be taken for granted. The study further recommends the Ministry of Education (MOE) and Teachers Service Commission (TSC) to ensure the compulsory training of all newly appointed principals, deputy principals, Board of Management (BOMs) members in the public secondary schools.

**Key words: Politics, institutional leadership, politicism, politicians, leadership, principal.**

## Background to the Study

School leadership and management styles apply universally throughout the world as challenges are the same. However, leadership cannot be imported in the same way in each country because leadership styles are varied across countries and are not exercised in the same way across different cultures (Unal, 2017). Cultural diversities influence school leadership (Ssekamwa, 2001). The traditional and cultural foundation of the communities around the schools can determine the institutional leadership. Culture and education should run in harmony. Principals should therefore understand the culture of the school community. In addition, politics fashions education and education modifies politics. According to Ijov and Alye (2015), no one can take politics out of education because it is not an academic problem or a legal one; rather each citizen is a stakeholder.

Hence the reality is, there is no education system that can be separated from politics. In Africa, the government is a major actor in the ownership, finance and control of educational institutions (Akpakwu & Okwo, 2014). In Nigeria like any other African country, there are no formal procedures for preparing and developing school leaders. In South African schools, many principals are either not coping with the numerous changes or they do not have the necessary skills, knowledge and attitudes to manage schools effectively and efficiently.

In Kenya, the cultural diversity of human beings has been one that involved the interaction of various communities since time immemorial. Since schools do not exist in a vacuum, the political nature of public secondary schools in Kenya cannot be avoided or taken for granted. The close relationship between politicians, the community and the public secondary schools' leadership has cemented the influence of politics in education. According to Abbasialiya (2010), principals in Kenya secondary schools have no choice but to interact continually with the changing unstable environment to survive since their schools' boundaries are permeable. Most public secondary schools in Kenya have received assistance from politicians in one way or another due to lack of adequate physical facilities and resources. In turn, the politicians influence appointment of principals, teachers, BOMs, admission of students, and most importantly, allocate resources to public secondary schools along political strongholds, sectional boundaries, clans and other areas where they enjoy "catchment politics". On the other hand, schools in "opposition zones" do not benefit much due to poor resource allocations.

Due to the multi ethnic nature of Kajiado County, the practice of "clan politics", "catchment area politics" and "clan balancing" is a common phenomenon. *Clan politics* in the Maasai community is largely about competition for resources between clans. *Clan politics* have been employed by the various tribal sections of the Maasai community as a way of pursuing clan interests without arousing the curiosity of the "onlookers' (individuals who condemn the traditional practices of the Maasai) as "primitive" while rejoicing over their marginalization (Ernestia, 2000). *Catchment area politics* and *clan balancing* have been used to influence and share out recruitment and appointment slots and allocation of resources between the various clans in the communities and to a large extend in the allocation of resources in public secondary schools. Politics and allegiance to culture is a reality in education that cannot be overlooked at any cost. Thus, principals must be conversant with how to manage the political realities that have befallen almost all public schools (Ugochukwu, Kalagbor & Harrion, 2016). The study focused on examining the governance and leadership challenges arising from the influence of politicism in the public secondary schools' leadership and management functions.

## Statement of the problem

In spite of the concerted efforts by the Teachers Service Commission (TSC) to recruit, appoint and install principals and teachers, and the Ministry of Education (MOE) role in the education sector, cultural and political influences continue to affect institutional leadership in public secondary schools in Kajiado County. This is evident from the nature of influence the external social environment has over the public secondary schools. Allegiance to culture, traditions and politics by communities around public schools have played a significant role in influencing the nature, status and composition of leadership in each particular public secondary school in Kajiado County. As a result, some public secondary schools receive grants, bursaries and donations depending on clan politics and alliances, catchment area politics, who knows whom, which sectional boundaries the schools are located as well as the incumbent political leaders. Appointments to principalship and allocation of resources to schools must comply with the laws of the country. It should not be discriminatory. There is very little evidence of research done to investigate the influence of politics on institutional leadership in public secondary schools in Kajiado County. This study strived to fill that knowledge gap.

## Objective of the study

To investigate the influence of politicism on institutional leadership in public secondary schools in Kajiado County, in Kenya.

## Research question

To what extent does politicism influence institutional leadership in public secondary schools in Kajiado County, Kenya?

## Literature review

### Institutional leadership and principalship

The concept of institutional leadership could be defined as the shared capability of management to detect and cope with changes in the external environment by upholding the most important objectives of the organization. It is the institutional leaders' role to maintain the legitimacy of their institutions to ensure their survival (Washington, Boal & Davis, 2007). In addition, an institutional leadership should operate towards greater excellence and performance of the institution that will propel the institution to greater achievements. The principal is the leader in a school, the pivot around which many aspects of the school rotate. According to Ondieki (2011), the increased sense of uncertainty in the community and its many social issues find their way into the school gate. In Kajiado County, public schools as institutions are particularly prone to political activity due to the sectional interests of different groups, which leads to the prevalence of politics, clanism and division into camps within the schools. As a result, the goals of the various groups most of the times conflict with one another because a focus on one objective may be at the expense of another (Bush, 2011). Hence, schools are influenced by the communities in which they exist. There is need for the educational institutions to address the pressure and outside influences so as to remain afloat.

### Politicism on Institutional Leadership

Politics is a kind of game play that involves activities which people enter into to pursue groups, personal or selfish interests or ulterior motives (Ozumba & Ebuara, 2014). Politics according to

Akpakwu and Okwo (2014) is a struggle over values, power and scarce resources in which the aim of the conflicting interests are to gain the desired values and resources at the expense of their rivals. Political interference hinders effective secondary school governance. The so-called political influence in public secondary schools is labeled as public interest (Xulu, 2001). It is a ploy by politicians to erode the values and dignity of schools (Akpakwu & Okwo, 2014).

In Africa, political influence and cultural issues are some of the major school dilemmas facing principals. Ifeanyichukwu, Ikechukwu and Faith (2016) posit that, the administrations of secondary schools are now acting on the dictates of the political actors. The political order of the society sets pace for education. Education is the servant and product of politics (Ijov & Alye, 2015). According to Ali (2011), schools are about people. Schools are not an isolated part of the society. Sussy, Abwire and Simon (2012) further assert that, political influence has been a thorn in the flesh in many public secondary schools. Schools as public institutions do not exist in a vacuum. There is a strong connection between schools and the political institution because schools as institutions are directly related to the community, county governments or state. Schools are inherently political and the role of a school principal is also political. It is therefore true to say that "you can take education out of politics but you cannot take politics out of education". Politics is an unavoidable phenomenon in every society (Osuji, 2011). The administration of secondary schools cannot be devoid of the influence of the politicians because education is the sub-structure of the super-structure, which the political system represents (Ifeanyichukwu, Ikechukwu & Faith, 2016). Politics makes administration of schools to be mere robots in the dispensing of their jobs. According to Kreuzer (2005), the central duty of any political individual is to promote the interests of the clan by whatever means even if through uncouth means.

In Kajiado County where the study was conducted, the multi ethnic and multi-cultural nature of people has made institutional leadership to be more vulnerable to political manipulations and influence. 'Political pressure' and 'political influence' is a reality faced by education officers, TSC officers and principals in public secondary schools in Kajiado County. The education system and institutional leadership cannot be said to be free from the clutches of domestic politics (clan politics) and dictation by political kings. Cultural diversities influence school leadership due to the locations of schools and the dominant culture underpinnings (Otunga, Serem & Kindiki, 2008). In addition, politicians have watered down the public secondary school's administration (BOMs and PTAs) and the education offices to accommodate their primitive interest. Packing BOMs with political faithful and stooges affects the administration of public schools negatively since the BOMs in return ensure that their loyalists are occupying other leadership or employment positions under them (Akpakwu & Okwo, 2014). Sometimes the education office is compelled to make decisions under pressure from political leaders (Ali, 2011). According to Osuji (2011), politics controls the school system.

According to Bigham and Ray (2012), the challenge facing school leaders is to admit the reality that politics is a part of the everyday routine in their schools. To ignore political issues or consider political activity as unworthy of an educational leader is to leave the school, its staff, pupils and parents vulnerable to competing social forces (Martin & Geoff, 2005). Time is rife for principals to become “political savvy” and develop political skills that will help them navigate the political terrains within which the public secondary schools exists (Ugochukwu, Kalagbor & Harrion, 2016). Good educational leaders must use politics to their advantage (Bigham & Ray, 2012). Principals need to be ‘tactful’ while working with political figures in the community (Ali, 2011). Political manoeuvrings in the administration of public secondary schools should not be tolerated at all.

**Research Methodology and Design**

The study adopted the mixed approach of research and the concurrent-triangulation design (Tashakkori & Teddlie, 2003). Both quantitative and qualitative approaches were used in data collection by use of questionnaires, interview guides and document analysis checklists. Quantitative data were analyzed descriptively and inferentially. Descriptive statistics was analyzed using frequencies and percentages and presented using tables. Inferential statistics was analyzed using multiple regressions and presented in tables. Qualitative data was analyzed thematically and presented in narrative form and direct quotations. Qualitative data that could be quantified were quantitatively analysed and summarized descriptively by use of frequency and percentages.

**Target population**

The target population involved 783 participants comprising of 8 education officers, 60 principals, 60 deputy principals and 655 teachers.

**Sample size**

Out of the target population, the study sampled 25 principals, 25 deputy principals, 185 secondary teachers in selected public secondary schools within the County. One education officer was selected from each of the five constituencies in the County. Schools were classified according to strata as follows: 2 National schools, 7 County schools and 51 District schools.

**Research findings and discussions**

**To investigate the influence of politicism on institutional leadership in public secondary schools in Kajiado county, in Kenya.**

The summary of the research findings and discussions have been presented as follows.

**How assistance provided by politicians could become a problem to public secondary schools**

A good understanding of the relationship between politics and institutional leadership is paramount to any principal because politics can contribute positively or negatively to the public secondary schools as presented in Table 1.

**Table 1: Teachers views on effects of assistance provided by politicians to the secondary schools**

| **Statements** | ***f*** | **%** |
|---|---|---|
| Attach support given to schools to get political mileage | 9 | 47.4 |
| Distribution of resources is linked to political goodwill | 8 | 42.1 |
| Tenders and contracts given to cronies and close acquaintances | 7 | 36.8 |
| Principals expected to sing the tune of the politicians-demand allegiance | 6 | 31.6 |
| Politicians control most schools since they are the one determining who is to become a BOM | 5 | 26.3 |
| Brings rivalry in the school when politicians fight for political support | 5 | 26.3 |
| Influence admission of students | 4 | 21.1 |
| Withdraw support from schools | 2 | 10.2 |
| **Total** | **132** | **100** |

Table 1 show that 9(47.4%) of the teachers said that politicians attached support given to schools to get political mileage, while distribution of resources was linked to political goodwill at 8(42.1%). Additionally, awarding of tenders and contracts by politicians to their cronies at 7(36.8%) was cited as another main problem linking the assistance provided by politicians to schools. It was further established that politicians demanded allegiance from the principals at 6(31.6%). Politics was also linked to control of schools through BOMs 5(26.3%) and rivalry between politicians as they fight for support from parents and the community 5(26.3%). Political differences should not spill over to secondary schools (Xulu, 2001). This implies that schools, as public institutions do not exist in a vacuum. There is a strong connection between schools and the political institutions because schools are directly related to the community, county and state governments.

**How politics affects governance and leadership in public secondary schools**

Political interferences hinder effective governance and leadership in the public secondary schools. The effects of politics on the governance and leadership in secondary schools are presented in Table 2.

**Table 2: Principals views on effects of politics on governance and leadership in secondary schools**

| Effects of politics on governance and leadership in secondary schools | *f* | % |
|---|---|---|
| Yes | 17 | 89.5 |
| No | 2 | 10.5 |
| **Total** | **19** | **100** |

Table 2 shows that, 17(89.5%) of the principals agreed that the exposure of secondary schools to politics affected the governance and leadership in most secondary schools. Only 2(10.5%) of the principals said it does not affect. According to Xulu (2001), secondary schools should be political free-zone and that schools should remain purely educational institutions. Sussy, Abwire and Simon (2012) further assert that, political influence has been a thorn in the flesh in many public secondary schools. This finding implies that political pressures and political influences is a reality in many public secondary schools, hence it effects are felt in decision-making and the running of schools.

**Influence of politicians on secondary school leadership**

In many public secondary schools, political interests continue to supersede the interests of the schools. Table 3 presents the results of the views of teachers on the influence of politicians on secondary school leadership.

**Table 3: Teachers views on the influence of politicians on secondary school leadership**

| Statements | Never | | Seldom | | Occasionally | | Often | | Always | |
|---|---|---|---|---|---|---|---|---|---|---|
| | # | % | # | % | # | % | # | % | # | % |
| Principals/ teachers who are not in the good books of politicians are transferred/not promoted | 15 | **11.4** | 19 | **14.4** | 68 | **51.5** | 19 | **14.4** | 11 | **8.3** |
| Principals/teachers who have godfathers are promoted/not transferred | 16 | **12** | 20 | **15.2** | 34 | **25.8** | 35 | **26.5** | 27 | **20.5** |
| Politicians influence the recruitment of teachers in secondary schools in favour of the local community | 26 | **19.7** | 26 | **19.7** | 41 | **31.1** | 23 | **17.5** | 16 | **12** |
| | 8 | **6** | 31 | **23.5** | 48 | **36.4** | 26 | **19.7** | 19 | **14.4** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Some BOMs are cronies of the politicians | 20 | **15.1** | 31 | **23.5** | 45 | **34.1** | 19 | **14.4** | 17 | **12.9** |
| Politicians influence tender/contracts in the secondary schools | 26 | **19.7** | 26 | **19.7** | 47 | **35.6** | 18 | **13.6** | 15 | **114** |
| Principals receive favours from politicians | 19 | **11.4** | 15 | **11.4** | 42 | **31.8** | 31 | **23.5** | 25 | **18.9** |
| Politicians control the education system in Kenya | | | | | | | | | | |

Table 3 shows that the most common influence of politics on secondary schools are the *occasional* transfer / promotion of teachers and principals as indicated by 68(51.5%), *often* teachers with godfathers are promoted/not transferred at 35(26.5%), *occasionally* some BOMs are cronies of politicians at 48(36.4%). Other responses include principals *occasionally* receiving favours from politicians 47(35.6%), politicians *occasionally* influencing tender/contracts in the secondary schools at 45(34.1%), *occasionally* politics controlling the education system in Kajiado at 42(31.8%). These findings imply that politicians have succeeded in undermining leadership in the public secondary schools because the institutional leaders have also chosen to play their games and compromise their dignity and integrity, thus failing to protect the institutional values they are supposed to safeguard.

To verify the possibility of influence of politicism on institutional leadership in public secondary schools, data was collected from principals on how they rate the influence of politics on public secondary school leadership in Kajiado County and the results are presented on Table 4.

**Table 4: Statistical measurement on the rate of influence of politics on secondary school leadership**

| **Dependent variable: Institutional leadership** | | |
|---|---|---|
| | **Regression statistics** | **Politics** |
| Predictor: Politics | R | .858 |
| | R-squared($R^2$) | .737 |
| | Adjusted R squared($R^2$) | .735 |
| | Beta β | .858 |
| | p-value | .000 |

| | |
|---|---|
| Standard error of estimate (E) | .25616 |

Table 4 portrays results of a simple linear regression analysis on the rate of influence of politics (predictor) on institutional leadership in public secondary schools in Kajiado County. The Pearson's R=.773 indicates that there was a strong positive relationship between politics and institutional leadership in public secondary schools in the study locale. The R-squared ($R^2$) computed yielded a value of .598 suggesting that politics explained (59.8%) of the variations in institutional leadership in public secondary schools in Kajiado County. The adjusted R-squared ($R^2$) =.574 confirmed that politics explained (57.4%) of the variations in institutional leadership. The *p*-value computed by SPSS yielded a value of.000 which is less than the significance level of $p<.001$. This led to the conclusion that there was a statistically significant relationship between politics and institutional leadership in public secondary schools in Kajiado County. Politics and education thrive in a symbiotic liaison each affecting the other simultaneously (Xulu, 2001). These findings imply that politicians as leaders have a strong influence on the management of public secondary schools. As pointed out by Osuji (2011), politics controls the school system.

In addition, 68.4% of the principals said that politicians provided financial assistance as well as infrastructural development to their schools when they build classrooms, laboratories, dormitories, and administration blocks, pay BOMs teachers and help in the fundraising. 47.4% of the principals had received bursaries and scholarships for needy students. As one principal reported:

*"Sometimes the public view the cooperation between the principal and the politician as patronage in the event that the school accepts donations. Political opponents then use this opportunity to side line and mudsling the principal and the school."* (22nd May 2017)

The study further revealed that politics affected the governance and administration of secondary when politicians influence the selection of BOMs and PTAs mostly their cronies and sycophants to foster their agenda and maintain their grip on the schools. One of the female principal interviewed reported that:

"*Schools have become products of political systems. To become a principal, political interest should supersede interest of the school*." (31st May 2017)

This comment suggests that vested interests can override and influence the school and the ministry goals and objectives hence affecting the leadership effectiveness and efficiency in many institutions. According to Xulu (2001), political influence in secondary schools is labelled as 'public interest'. Politics has also created scenarios where people are subjected to unwarranted scrutiny before being hired as teachers by the BOMs. As one female principal stated:

*"You don't mess around when a politician has vested interest in your school."* (31st May 2017)

The study further found out those areas where the politicians do not have supporters (opposition areas) are not allocated resources fairly hence some schools have better infrastructure than others. It was also revealed by the education officers that politics also brought misunderstanding on implementation of ministerial and school policies and decision making in the public secondary schools. Oduol (2014) attests that some politicians defy ministerial policies and directives (such as admission of students) and even laws when handling school matters. In addition, responses captured from the deputy principals by use of the document checklist showed that 100% of the secondary schools visited had documents like the TSC code of regulations (100%), the Basic Education Act (100%) and the Constitution of Kenya at 100%. However, 100% of the public secondary schools visited did not have the Bribery Act 2016, Ethics and Anti-Corruption Act at (90.9%), the Anti-Corruption and Crimes Act at (90.9%), Leadership and Integrity Act 2012 at (63.6%) and the Public Officers Ethics Act 2013 at (49.1%). Principals are expected to be conversant with these relevant and legal documents to operate within the safe precinct of the laws of Kenya because lack of these documents might compromise the leadership of principals and BOMs in the public secondary schools.

**Conclusions**

The study concludes that politics makes both positive and negative contributions towards the education sector. There is a strong connection between the education system and the political institution because politics and education thrive in a symbiotic liaison each affecting the other simultaneously. However, the institutional values must be defended at all cost and upheld at all times.

**Recommendations for practice**

The study recommends that, the MOE and TSC should ensure the compulsory training of all newly appointed principals, BOMs in the public secondary schools and incorporate the local and national politicians in the training. The contributions of politicians towards the education sector should not be taken for granted.

Secondly, public secondary schools should be completely free from political interferences. Those principals who carry out their duties diligently and against the selfish interest of politicians should not be punished. The government through the MOE and the TSC should remove the hands of political hawks from schools and ensure that political interference is minimized or eradicated from public secondary schools so that they remain environment of professionalism.

**Acknowledgement**

The success of this study has been attributed to the efforts of Dr. Ruth Thinguri and Dr. Anne Muiru for their mentorship, positive criticism, guidance and unconditional support. I cannot forget to acknowledge all the principals, deputy principals, education officers and teachers in all the public secondary schools that I visited for providing a conducive environment and assisting me in the collection of data.

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**Article 22**

# School culture and learning in STEM: Creating space for in/out of school STEM learning and application

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**Abstract**

The paper identifies the need for active responsiveness towards learning to equip the learners with the necessary knowledge, skills and values. The paper argues on the need for creation of learning space whose climate promotes the process of learning through active learning strategies that inspire learners to learn actively that needs to be created by the teacher. The custom instructional approach of teacher centered learning doesn't give equal opportunity to all learners in the learning process since it is competitive and individualistic among the learners. It's not responsive enough to empower and capacitate learners with skills in readiness to STEM learning and its application. From the data analyzed for three science subjects, the findings indicate learners' lack of necessary learning skills which empower them in exams as indicated by majority of low grades recorded in their *KCSE* final exams. This depicts lack of capability of learners to process knowledge for its application in exams. Learning in STEM should be structured in such a way that the learners can be analytical on information in an attempt to acquire knowledge and create problems' solutions through application.

**Keywords**: *Learning space, process of learning, active learning strategies, skills, knowledge, application.*

**List of tables**

**List of figures**



**Abbreviations**

| | |
|---|---|
| CEMASTEA | Center for Mathematics, Science and Technology in Africa |
| DOS | Dean of Studies |
| KCSE | Kenya Certificate for Secondary Education |
| KNEC | Kenya National Examination Council |
| STEM | Science, Technology, Engineering and Mathematics |

## Introduction

Currently, the society is challenged with changing demands from the workforce, an explosion of information that requires a great deal of sophistication to navigate, and increasingly complex thinking to make every day decisions (Yotam, 2017). As technology advances reducing the need for workers to complete routines, focus on people is more on solving strategic problems and thinking creatively (Lamb, Maire, and Doecke, 2017). In reference to the *Future of Jobs Report* by The World Economic Forum (2018), workers are expected to be more creative and innovative as well as learning actively and learning strategies to be competitive and adaptable in the work.

Therefore, it's very critical for the 21$^{st}$ century learners to acquire 21$^{st}$ century living skills in their learning process that will make them adaptable and competitive in their future. The quality of teaching is the most critical in-school factor impacting on learners' outcome which is facilitated by the learning culture of the school, individual teacher's pedagogical knowledge, skills and dispositions towards learning (Macharia, 2019).

In order to create a school culture that promotes the quality of teaching, an inviting space whose climate inspire students to engage actively in learning, needs to be created by the teacher where students are allowed to explore information through high order thinking skills and get exposed to new learning experience on their own in an effort to acquire new knowledge and its application.

## Teacher centered learning

For quality teaching, there is need for the teacher innovativeness in teaching & learning by adopting the most appropriate instructional approach to facilitate learning through application.

The instructional approaches commonly involved in the facilitation of learning include teacher-centered learning and learner-centered learning. In teacher centered learning, teacher's control of the classroom is of primary importance since authority is transmitted hierarchically as the teacher control the learners since compliance is valued over initiative and passive learners over active learners, (Garret, 2008).

Through the approach, learners struggle to internalize and live up to their roles as creators since they only heave knowledge (Kasoomile et al, 2019). In designing class activities, the teacher controls every single learning experience. In this scenario the student put all of their focus on the teacher and during the activities, students work alone and collaboration is discouraged. The approach focuses on the teacher as the driver of learning, students being passive learners (CEMASTEA 2017). This promotes competitive and individualized behavior among the learners since they access less opportunity to learn independently (Emiliana, 2017).

**Statement of the problem**

Lack of effort for innovative teaching and learning strategies that are learner-centered leads to many teachers adopting teacher-centered learning as the instructional approach to learning. This consists of lectures and text books reading which leads to poor understanding of the knowledge and its application in the STEM subjects. This is because, there is less interaction of students with what they study, lacking the ability to motivate and engage their interests, skills and creativity to study STEM subjects. Consequently, this leads to low or lack of necessary skills acquisition by the learners resulting to poor performances in their exams.

**Purpose of the study**

The purpose of the study was to evaluate the effectiveness of creating a conducive learning space to facilitate learner-centered learning that is active as opposed to teacher centered learning in an attempt to improve teaching and learning of STEM subjects. This is because the teacher has to focus on the learner in thinking about learning for knowledge must be applied for learning to occur since it's an interpretation of the reality. Learners' involvement in active learning activities enables them to relate abstract concepts to concrete examples and to translate scientific principles to scientific applications which contribute to students' better understanding of the scientific knowledge and its application. When well organized, learner-centered learning which is active can be an effective teaching and learning strategy for STEM subjects.

**Research questions**

1. Why is it important for the teacher to be innovative in teaching?
2. How can the teacher facilitate learners' skills acquisition?
3. What is the expected outcome of creating a conducing learning space?

## Literature review

The integration of knowledge, skills and abilities required in the professions support the use of active learning approaches early on, where meaningful learning promoting a deeper understanding is core (Mayer, 2002). This may be reflected by the use of a social-constructivist approach and learning activities such as problem-based and enquiry based methods (Zainnuddin et al, 2018).

Learning should be accommodating to all so that learners are motivated in exploring information and appreciating knowledge that comes with it through its application without being disadvantaged. On this basis, the learners have a different understanding of the knowledge depending on their experience, and the perspective used in interpreting it. Students create their own meaning through experience, (Adang, 2018).

## Creating Learning space

The acceleration rate of societal change along with technological innovations has expanded the notion of learning space, (Yatom, 2017). In work which specifically highlights 'space' or 'environment', the meaning is usually related to the instructional approaches in which teaching and learning are conceptualized or organized, rather than to do with physical arrangement. Classroom as a learning space is a multifaceted concept that includes the organization of the physical environment and the establishment of rules and routines (Garret,2008).

A conducive climate of the learning space exposes the learners to new learning experiences, and motivates them to learn more actively by taking charge of the process of learning. It involves learners and their teachers in diverse cognitive, affective and psychomotor functioning, evaluate each other's position in a view to coming up with a solution to a problem collectively (Smith, Neratzi and Middleton 2014). Its capacity and pattern must be adaptable to conform to the nature of learning in developing the students' skills and knowledge (Oblinger, 2006).

A conducive learning space can be considered in terms of the learning design approach and learning strategies adopted by the teacher for the learners. It's one in which experiences are structured in such a way that students have an opportunity to investigate, explore and experience learning by developing new ideas and insights (Leslie, 2014).

## Pivotal role of the teacher.

In order to create an inviting learning space, the teacher plays a key pivotal role in an effort to design and model a learning environment that involves active learning strategies that can enhance students' ability to learn through application. Therefore, the teacher fosters learning by creating a learning space climate that can either increase or decrease learning depending on the comfort of the students (Bucholz and Sheffler, 2009).

The effort put by the teacher (Jordan, Metais, 2000), can help the learners, as the future citizens, to go through an education system to become creators and not consumers as they should be able to analyze information for creativity in solving complex problems (Myer, 2018)

## Learning strategies

According to Sakala and Banda (2019), learner centered approach to teaching and learning motivates learners to be reflective, think and do rather than reproducing from rote learning. Teaching and learning process must be related to the practical real world where the learning space is designed and shaped in such a way that teachers and students can share their knowledge and experiences actively (Adang, 2018). In active learning the focus of instruction shifts from the teacher to the learners with the aim of developing their autonomy and independence. According to Rodgers (1983) as cited in TEAL (2010), by putting responsibility for the learning path in the hands of students, it allows them the liberty to choose the area of learning by coming up with the aims of the engagement in the process. This allows objective analysis for creativity and evaluation of their learning to develop their expertise, rather than accumulating matter, by constructing upon and questioning prior learning, (Weimer,2002).

The learning strategies need to facilitate active engagement of students with course materials through interactive lecture, discussions, hands-on technology, problem solving, brain storming, inquiry learning, active review sessions, role plays, case studies, experiential learning, kinaesthetic and tactile learning, edutainment etc., in order for them to develop learning skills. These will help the learners to develop the ability to translate abstract concepts to concrete examples and scientific principles to scientific applications. This promotes students self-assessment and employment of various coherent approach in categorization, contrasting and conception of new learning by thinking critically (Peko & Varga, 2013).

Through active learning, the learners get engaged for them to come out in taking challenges and exploring new aspects of knowledge as the teacher takes a back seat. Active engagement as a learning strategy is the most desired learning approach in acquisition of skills for profession adaptability (World Economic Forum, 2018). In addition to this, educational researchers have expounded on the need for active learning to increase involvement and learning by students (Rand and Gansemer-Topf, 2017). This is because learning actively involves the learners by becoming in-charge of setting their goals and develop potential to solve problems on their own (Robert 1985).

Active learning strategies steer learners towards tasks accomplishment as they are motivated to do so. Students are motivated to go through a demanding task by making them to be in control of exerting the direction in which learning takes place for new learning experience (Brunner, 1960). This makes them to have keen interest when they use their acquired skills in coming up with solutions to solve problems that they encounter (Lombardi, 2007 as cited by Boholoni, 2017).

## Learning skills

Learning in STEM and its application should help the learners to develop high order thinking skills when processing information in an attempt to gain new knowledge and by translating it into new application. Therefore, students must be involved in such high order thinking activities that involve analysis, creation, and evaluation (Bonwell, Elson 1991).

McCoog (2008) as cited in Boholano (2017), states that for students to learn skills, they must be analytical on information provided by applying the knowledge learnt through creativity which translates to new ideas. To assist students in acquiring high order thinking skills is contemplated as an exception learning design (Zohar & Dori, 2003). Consequently, skills are always advanced when organized and blended by an individual or a group of people with the intention of learning (Muste, 2016).

In the application of high order thinking skills, students' support in and out of school on STEM learning and its application must be enhanced to increase students' self-confidence and self-efficacy. This is through exposure to the real world learning experiences such as contests, exhibitions, symposiums, field trips and industrial exposure. Out of class learning experience positions students in a situation that motivates them to learn through real life experiences which makes learning more meaningful and interesting (Sulaiman, Muhbob and Azlan, 2011). Therefore, a fruitful learning culture is not only created within the classroom, the learning space outside the classroom must also be created to enhance the learners acquired skills and the applications of knowledge (Grimes2011).

## Methodology

### Procedure

The study employed qualitative and quantitative analysis of data from KCSE grades and subjects means for candidates in Mt Kinangop girls Secondary School in three STEM subjects (biology, chemistry, and physics). The data obtained for grades and subject means analyzed was from the year 2015-2019. Using Microsoft excel spreadsheet, the grades of the learners were grouped per year and the mean score calculated. The data analyzed consisted grades of 621 candidates in chemistry, 431 in biology and 200 in physics.

### Source of the data

The data analyzed was obtained from DOS office database obtained from KNEC from the year 2015 to 2019.

### Data

*Table 3.1 KCSE grades distribution in Chemistry and the mean scores of the subject per year.*

| | | **GRADES** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEAR** | **SUBJECT** | **A** | **A-** | **B+** | **B** | **B-** | **C+** | **C** | **C-** | **D+** | **D** | **D-** | **E** | **MEAN** |
| 2019 | Chemistry | 0 | 0 | 1 | 3 | 5 | 7 | 13 | 7 | 13 | 58 | 34 | 1 | 3.76 |
| 2018 | | 0 | 0 | 2 | 5 | 7 | 6 | 9 | 14 | 14 | 41 | 3 | 0 | 4.745 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2017 | | 0 | 0 | 0 | 2 | 5 | 6 | 3 | 9 | 2 | 44 | 50 | 1 | 3.311 |
| 2016 | | 0 | 1 | 1 | 3 | 8 | 6 | 11 | 10 | 17 | 58 | 13 | 0 | 4.203 |
| 2015 | | 0 | 0 | 0 | 4 | 5 | 32 | 22 | 24 | 18 | 17 | 6 | 0 | 5.367 |

*Table 3.2 KCSE grades distribution in physics and the mean score of the subject per year*

| | | GRADES | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEAR** | **SUBJECT** | **A** | **A-** | **B+** | **B** | **B-** | **C+** | **C** | **C-** | **D+** | **D** | **D-** | **E** | **MEAN** |
| 2019 | Physics | 0 | 0 | 0 | 0 | 3 | 6 | 1 | 6 | 2 | 17 | 0 | 0 | 4.654 |
| 2018 | | 0 | 1 | 2 | 4 | 4 | 2 | 3 | 7 | 9 | 15 | 3 | 0 | 5.06 |
| 2017 | | 0 | 0 | 3 | 2 | 4 | 1 | 4 | 4 | 2 | 11 | 2 | 0 | 5.33 |
| 2016 | | 1 | 0 | 2 | 5 | 4 | 12 | 7 | 6 | 4 | 6 | 1 | 0 | 6.271 |
| 2015 | | 0 | 0 | 4 | 4 | 6 | 6 | 6 | 5 | 1 | 2 | 0 | 0 | 7.028 |

*Table 3.3 KCSE grades distribution in biology and the mean score of the subject per year*

| | | GRADES | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **YEAR** | **SUBJECT** | **A** | **A-** | **B+** | **B** | **B-** | **C+** | **C** | **C-** | **D+** | **D** | **D-** | **E** | **MEAN** |
| 2019 | Biology | 0 | 0 | 0 | 1 | 1 | 2 | 6 | 13 | 14 | 59 | 11 | 0 | 3.617 |
| 2018 | | 0 | 0 | 0 | 1 | 0 | 2 | 3 | 6 | 6 | 30 | 4 | 0 | 3.712 |
| 2017 | | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 6 | 44 | 37 | 1 | 2.774 |
| 2016 | | 0 | 0 | 1 | 5 | 6 | 16 | 12 | 17 | 6 | 23 | 2 | 0 | 5.330 |
| 2015 | | 0 | 0 | 1 | 4 | 8 | 5 | 7 | 19 | 15 | 30 | 3 | 0 | 4.761 |

## Data analysis

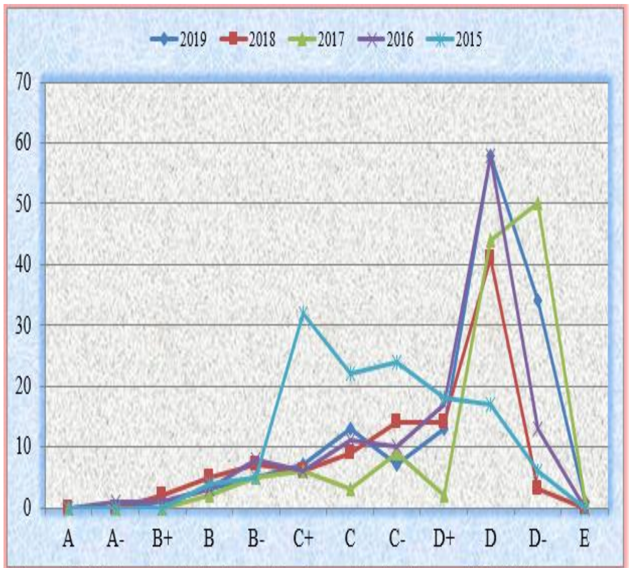


*Figure 4.1 KCSE grades distribution in chemistry subject for the year 2015-2019*

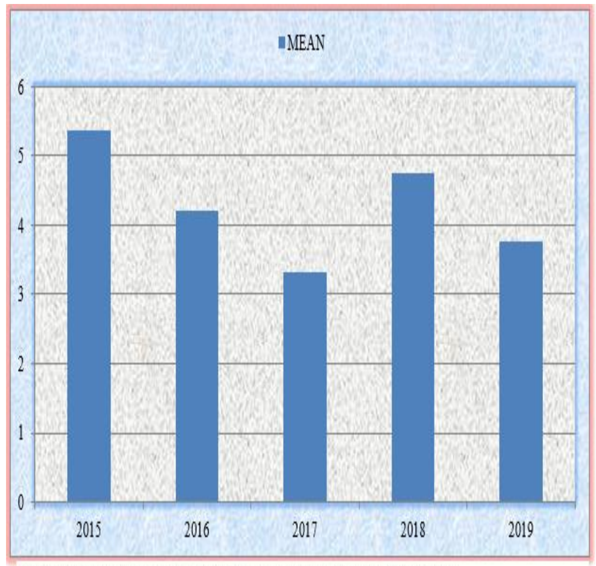


*Figure 4.2 Chemistry subject KCSE mean scores for the year 2015-2019*

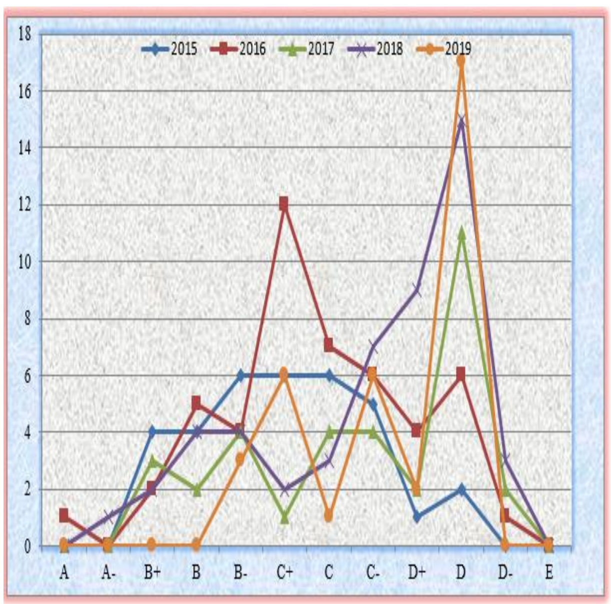


*Figure 4.4 Physics subject KCSE grades distribution for the year 2015-2019*

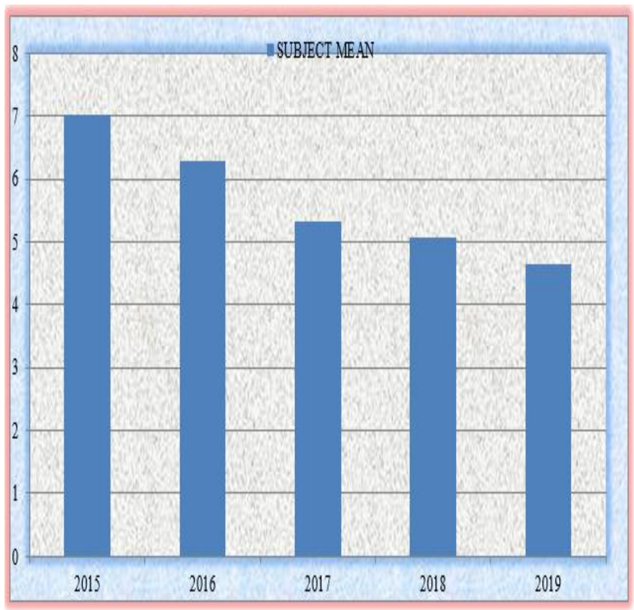


*Figure 4.4 Physics subject KCSE mean scores for the year 2015-2019*

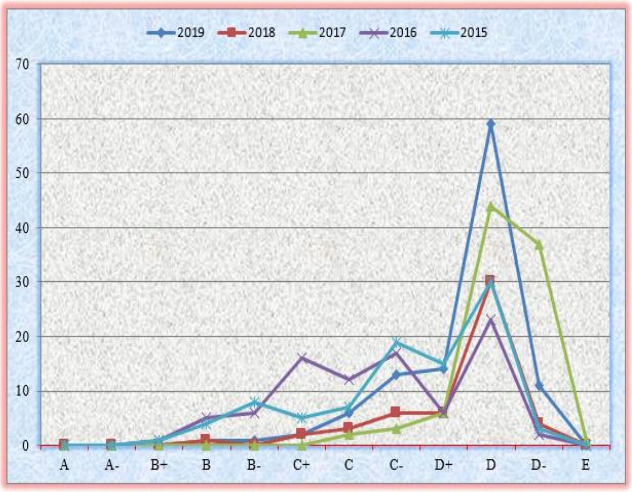


*Figure 4.5 KCSE grades distribution in biology subject for the year 2015-2019*

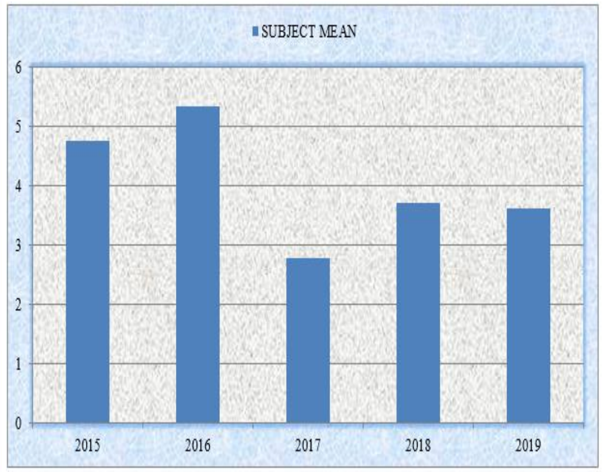


*Figure 4.6 Biology subject KCSE mean score for the year 2015-2018*

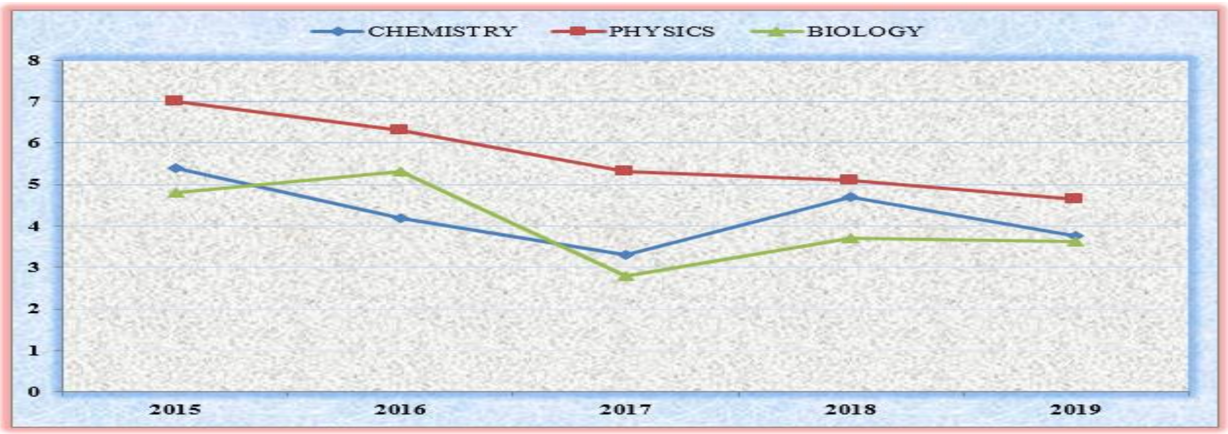


*Figure 4.7 Mean scores of three STEM subjects over a period of five years.*

**Discussion from the findings**

The results from the analyses of the three subjects obtained illustrated a wide variation in the grades and their mean scores attained by the learners in the *kcse* exams over a period of five years. The overall A and A- grades in all subjects were at minima while D grades were at the maxima.

In chemistry *kcse* results, C+ as a grade had the highest entries in the year 2015 as illustrated by *figure 1*. D grade had highest entries in the year 2016, 2018 and 2019. D- as a grade had the highest entries in the year 2017. Only one student recorded an E grade in the year 2017. None of the student scored an A grade throughout the five years except one with an A- in the year 2016. This made the subject means to remain below 5 since 2015. The subject mean recorded the highest of 5.3 in the year 2015 and the lowest of 3.3 in the year 2017 as illustrated by *figure 2*. In 2014 the candidates had recorded a mean of 4.9.

In physics *kcse* results, B-, C+ & C as grades had the highest candidates' entry in 2015 as illustrated by *figure 3*, C+ in 2016, D in year 2017, 2018 and 2019. There was progressive increase of D grades throughout the five years. None of the candidate recorded an E. Only one student recorded an A in the year 2016 and an A- in the year 2018. The trend of gradual increased grades entry from B- to D over the years made the subject mean continuously decrease from the year 2015 to the year 2019 as illustrated by the *figure 4*. The subject mean had a continuous decrease from 7.0 in 2015 to 4.6 in 2019. In 2014 the students had recorded a mean of 5.8.

In biology *kcse* results, D as a grade had the highest candidates' entries throughout the five years as illustrated by *figure 5*. Only one candidate recorded an E in the year 2017, while none recorded an A or A- as a grade throughout the five years. This made the subject mean to remain below 5 as illustrated by *figure 6*. The subject mean recorded the highest of 5.3 in the year 2015 and lowest of 2.8 in the year 2017. In 2014, the candidates had a mean of 6.4.

With the comparison of the three subjects mean scores over the period of five years as illustrated by *figure 7,* chemistry had a gradual decrease of the mean score from the year 2015 to 2017, an increase in 2018 and a decrease in 2019. In physics, the subject mean gradually decreased continuously over the period of the five years. In biology, the subject mean had an alternate increase and decrease over the period of the study.

Several factors could have contributed to this performance. In teaching and learning, the instructional approach adopted by the majority of the teachers was through teacher-centered learning. Only a few who adopted learner centered learning which was active. The main contributing factor to the adoption of this instructional approach by the teachers was due lack of pedagogical skills that would facilitate learner-centered learning. Many lacked initiatives to innovative learning as they termed it involving and time consuming. This resulted to many learners being denied the opportunity to develop their thinking skills which helps in processing of information to acquire knowledge and its application when solving problems.

## Conclusion

Teacher centered learning as the instructional approach leads to many learners low skills acquisition. Also, skills are not progressively nurtured from lower form to higher form with consistency. This results to most of the learners to keep on failing on their standardized internal exams which discourages many throughout the course. This results to many learners developing negative attitude towards the subjects of the study. Low skills acquisition by the learners during learning makes them to keep on performing poorly on any subject test given. This results to negative attitude towards the subject of the study which is manifested in in their performances.

## Recommendation

Through teacher centered learning as the instructional approach, it is common for only some few students in a given course to participate in asking or responding to questions where many get disadvantaged. In contrast, a class with successful active learning activities provides an opportunity for all students in a class to think and engage with course material and practice acquired skills for learning, create new knowledge leading to new ideas. Therefore, in order to create a school culture that promotes learning in STEM and its application, the teacher should use innovative learning strategies to facilitate an inviting space for learning that inspire students to engage actively in learning where they can explore and get exposed to new learning experience on their own in an effort to acquire new knowledge and its application promoting skills progression.

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**Article 23**

# The Formula for the image P (p, q) for the object A (a, b) in the mirror line y=mx +c

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**Abstract**

The image point (p, q) of the object point (a, b) under reflection in the line y = mx + c has been obtained in various ways in the past. Matrix method in particular was very common. In this sort of reflection, the mirror line was almost always through the origin O (0,0). Thus, every mirror line took the form y = mx. The aim of the study was to establish a simple straightforward formula linking the image point P (p, q) directly to the object point A (a, b) for a mirror line of gradient m and y-intercept c and c≠0. It was observed that (i) the object A (a, b) and the image P (p, q) were symmetrical about the mirror line y = mx + c, (ii) the gradient of the line through the object A (a, b) and the image P (p, q) was (-m-1), (iii) the midpoint between the object A (a, b) and the image P (p, q) was the point M$\left(\frac{a+p}{2}, \frac{b+q}{2}\right)$. Through rigorous process of substitution, elimination, simplification and verification it was established that for an object point A (a, b) under reflection in the mirror line y = mx + c the image point P (p, q) is given by $p = \frac{a(1-m^2)+2m(b-c)}{m^2+1}$, $q = \frac{b(m^2-1)+2(am+c)}{m^2+1}$

Thus p and q were expressed entirely in terms of a, b, c, and m regardless of the variables x and y. conversely the mirror line y = mx + c was deduced from the object point (a, b) and the image point (p, q) by determining the values of m and c. The formula is recommended for all reflections where the mirror line does not necessarily pass through the origin O (0, 0).

**Key words:** *Formula- a mathematical relationship between two or more quantities; Gradient-the ratio of vertical displacement to horizontal displacement; Matrix-a rectangular array of numbers; Origin-the reference point from which all measurements (horizontal and vertical) are taken.*

**Acronyms and abbreviations:** *CEMASTEA-Centre for Mathematics, Science and Technology Education in Africa; SMASE-Strengthening Mathemetics and Science Education; MoEST-Ministry of Education, Science and Technology*

## Introduction

Reflection in two dimensions is one of the various transformations investigated on in institutions of learning. Other transformations include, but not limited to, translation, rotation, enlargement, stretch and sheer. Apart from translation which can be represented using a 2x1 vector matrix, the transformations are generally represented using a 2x2 matrix. Reflection is one of the isometrics transformations whereby the shape and size of the image is the same as the shape and size of the object. It will be noted that matrix reflection in two dimensions is always in a line through the origin (0, 0); either in the x or y axes or in the line y = ±x. For instance, the object point (1, 1) has no image of matrix reflection in the line y = 0.5x. However, the formula predicts that that image of object point (1, 1) in the mirror line y = 0.5x is (1.4, 0.2)

**Methodology**

A Cartesian plane, (x and y axes), was drawn on a graph paper. The axes intersected at right angles at the origin O (0, 0). A straight line L of equation y = mx + c, was drawn on the Cartesian plane. L had a gradient = m and y intercept = c.

A point A (a, b) and its image P (p, q) in L was constructed such that L was the perpendicular bisector of AP. If the gradient of L was m and that of AP was $m^i$, then $mm^i = -1$. Thus,

$$-\frac{1}{m} = \frac{q-b}{p-a}$$

$$\rightarrow p = a + m\,(b - q)$$

$$\rightarrow q = \frac{a + mb - p}{m}$$

The midpoint M(x, y) of AP was given by $M(\frac{a+p}{2}, \frac{b+q}{2})$. Since M was in y = mx + c, it was easy to show that

$$\frac{b+q}{2} = \frac{m(a+p)}{2} + c$$

$$\rightarrow b + q = m\,(a + p) + 2c$$

$$\rightarrow q = m\,(a + \{a + m\,(b - q)\} + 2c - b$$

$$= m\,(2a + mb - mq) + 2c - b$$

$$= 2ma + m^2b - m^2q + 2c - b$$

$$\rightarrow q + m^2q = 2(ma + c) + b(m^2 - 1)$$

$$\rightarrow q(1 + m) = 2(ma + c) + b(m^2 - 1)$$

$$\leftrightarrow q = \frac{2(ma + c) + b(m^2 - 1)}{m^2 + 1} \quad \text{……………………..}\textit{eqtn1}$$

Similarly, from $b + q = m\,(a + p) + 2c$,

$$\rightarrow m(a + p) = b + q - 2c$$

$$= b + \{\frac{bm + a - p)}{m}\} - 2c$$

$$\rightarrow m^2(a + p) = mb + mb + a - p - 2mc$$

$= 2m(b - c) + a - p$

$\rightarrow m^2a + m^2p = 2m(b - c) + a - p$

$\rightarrow m^2p + p = 2m(b - c) + a - m^2a$

$\rightarrow p(m^2 + 1) = 2m(b - c) + a(1 - m^2)$

$\leftrightarrow \boldsymbol{p = \frac{2m(b-c)+a(1-m^2)}{m^2+1}}$ **………………………*eqtn2***

**Discussion**

The two expressions for the image point P (p, q) were put to the test as follows; the object was a polygon with vertices A, B, C and D. Their corresponding images were P, Q, R, and S respectively. The observations were tabulated as in Table 1 below. The object chosen was a square with vertices A (1.9), B (5, 9), C (5, 13) and D (1, 13)

Determining the image PQRS of the square ABCD with vertices A (1, 9), B (5, 9), C (5, 13) and D (1, 13) in the line y = 1.4x +2

Table 1.

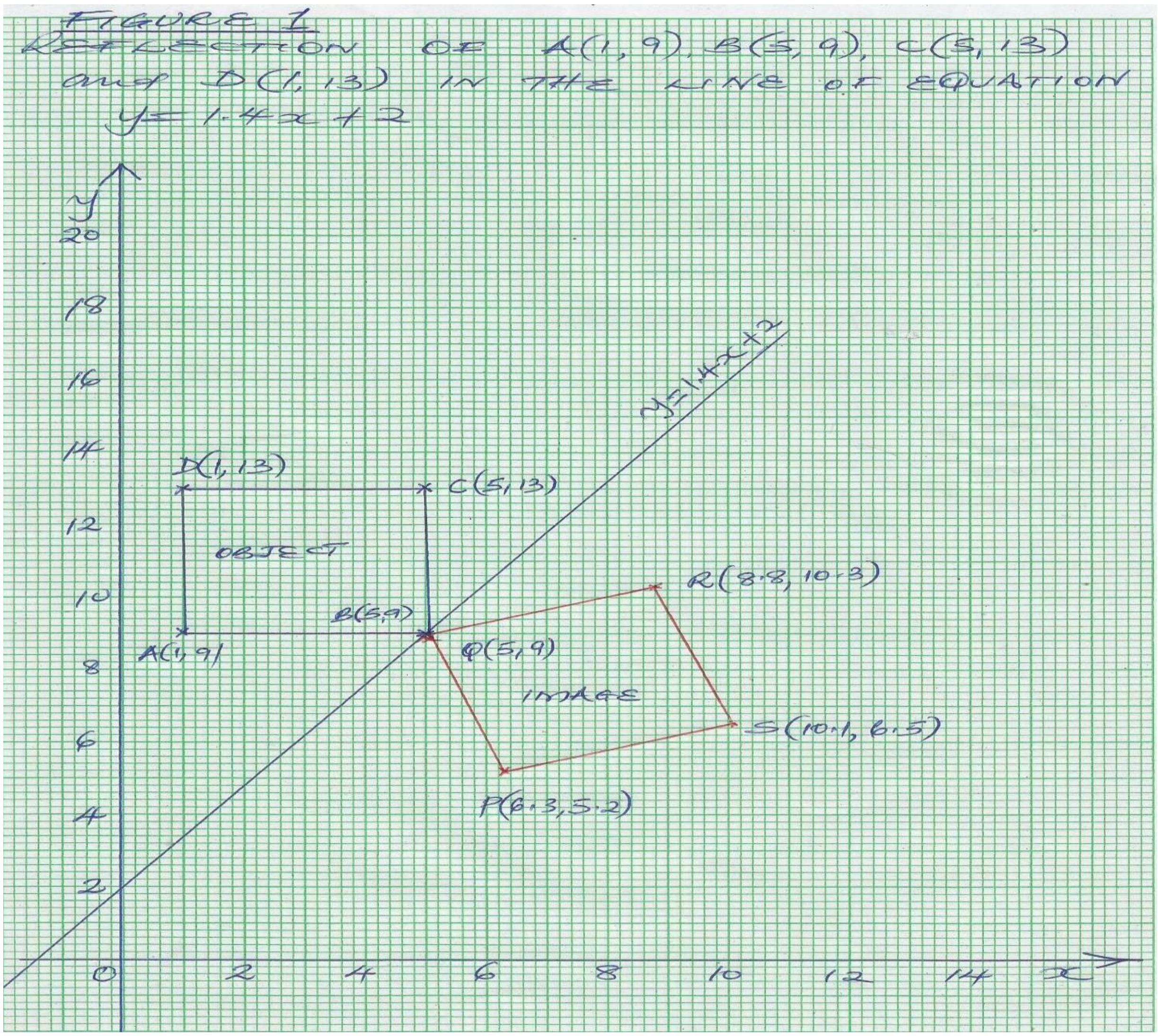
| *c* | *m* | $m^2$ | $m^2+1$ | $m^2-1$ | $1-m^2$ |
|---|---|---|---|---|---|
| 2 | 1.4 | 1.96 | 2.96 | 0.96 | - 0.96 |

| Object | Coordinates ($a$, $b$) | | image | Substitutions of ($p$, $q$) | | Coordinates ($p$ ,$q$) | |
|---|---|---|---|---|---|---|---|
| A | 1 | 9 | P | $\frac{-0.96 + 2.8X7}{2.9}$ | $\frac{9X0.96 + 2X3.4}{2.96}$ | 6.3 | 5.2 |
| B | 5 | 9 | Q | $\frac{9X(-0.96) + 2.8X7}{2.96}$ | $\frac{9X0.96 + 2X9}{2.96}$ | 5 | 9 |
| C | 5 | 13 | R | $\frac{5(-0.96) + 2.8X11}{2.96}$ | $\frac{13X0.96 + 2X9}{2.96}$ | 8.8 | 10.3 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| D | 1 | 13 | | S | $\dfrac{-0.96 + 2.8X11}{2.96}$ | $\dfrac{13X0.96 + 2X3.4}{2.96}$ | 10.1 | 6.5 |

(N. B. The values of m and c in y = mx + c were used repeatedly from one image point to the next. Therefore, it was more convenient to have a separate table for their substitutions).

The object and its image were then plotted on the Cartesian plane as shown in Figure 1 below.




It was necessary to take a shape with many vertices as the object points so that any deviation from the expected shape could be noted. For all the shapes used the formula worked very well. As illustrated above the formula was very easy to work with. It also gave more accurate results than would be obtained by construction.

## Conclusion

The formula will be found useful where the matrix method of reflection is insufficient, as it is applicable in all situations.

## Recommendations

There is need to extend the theory of reflection farther to include reflection in a three-dimensional space. Thus, a formula for the image P (p, q, r) of the object A (a, b, c) in plane H would be obtained.

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**Strand 4 # STEM Curriculum Development Implementation and Assessment**

1.Learner Engagement: Evidence-based Lessons on STEM / STEAM Education
2.Pre-Service Teacher Development: Abilities, Skills and Values

**Article 24**

# Rhetoric and reality of postmodernism in mathematics education: The implementation versus performance in the Botswana General Certificate of Secondary Education mathematics curriculum

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## Abstract

This study endeavored to unravel the reality of the envisaged learner-centred mathematics pedagogy as against the rhetoric that the curriculum developers espoused. This is on the backdrop of pronouncements on the mathematics syllabus whose rationale stated: To achieve the stated aims and objectives the teaching and learning of Mathematics is to be based on a learner centred approach. A variety of methods are therefore to be used such as exposition and consolidation, discussions, practical work, problem solving activities and investigative work. Furthermore, teaching and learning of mathematics should utilize modern technology such as the graphic calculators and computers that place mathematics in a realistic context. This will offer a constructivist view on mathematics to learners, promote interest and motivation, and prepare the students effectively for the next century paving the way for future generations. The research purported to find out whether the implementation of the mathematics syllabus was successful given the declining or stagnant results for the past five years. The learner-centred instructional implementation was meant to give learners more autonomy and the liberty to construct their own knowledge and hence improve instructional outcomes. However, the study has revealed the prevalence of poor performance in mathematics resulting from teacher-centred instructional methodologies. The study considered issues of curriculum implementation processes, the concept of learner-centeredness and teachers' readiness to engage in syllabus implementation given their current training and in-service professional development which was reflected to be at stalemate.

**Key words**: *postmodernism, curriculum implementation, mathematics syllabus, rhetoric and reality, learner-centred*

**Abbreviations:** *BGCSE- Botswana General certificate of Secondary Education, PT- Post Modern Theory*, *MMR- Mixed Method Research*

## Introduction

Arguments and observations over past few years, there have been significant changes in the mathematics curriculum aimed at improving teaching and learning. Because of observed poor results most of the mathematics curricula are focused on developing student knowledge through learner's discoveries and experiences during instructions. The learner centred method has been under development from 1950, it started as a person-centred education and then later converted to learner-centred education in 1990s (Cornelius-White, 2007). The person-centred education was more concerned with teacher empathy, on-directivity and encouragement of critical thinking. The learner cantered method focuses on all the domains as compared to the person-centre method (Cornelius-White, 2007, pp.113-115). In trying to make sense of the insights of these divergent perspectives of social reality and its existence. It is worth to establish the merits and limitations of considering the students in our classrooms as only collections of individual minds, in contrast with perspectives that posit the primacy of the social in determining the identity of mathematics learners. In mathematics, learner centred model, learners are who learn mathematics by doing to create discoveries; learners are an active part in the acquisition of their own mathematical knowledge (Flores,2010).The method is based on the pragmatic basis of "hands on "mathematics must be treated very like the process of learning a trade or apprenticeship, thus learners are mathematical apprentices that learn applying their knowledge in a workshop form(Flores,2010).The above statement confirms that the learners should be main characters on their learning process. Recent developments in analytical social theory may have the potential to address this issue productively (Kent, 2014). This study is well characterized by revealing the conflicting fact between rhetoric and reality of postmodernism perspectives in mathematics education. This attracts literature and the critical role of inter-subjectivity in communicating mathematics through interaction and exploring through project method by learners at BGCSE.

After several decades of the *Mathematics education policyrhetoric*in Botswana, the discipline of mathematics continues to be used for social stratification. Learners are often tracked or "sorted" per their perceived mathematics "abilities" (Stinson & Bullock, 2012).This (perceived) ability tracking continues to be a fundamental aspect of mathematics education despite research showing the positive possibilities of de-tracked mathematics classrooms (Boaler& Staples 2008).Most mathematical classes are influenced by Platonic Ideal: either a child possesses the aristocratic characteristic of intelligence or not, and those who do "should persist in their studies until they reach the level of pure thought, where they will be able to contemplate the very nature of number" (Plato,1996, p. 219). This discursive practice of linking (perceived) mathematics ability to intelligence, and thus to power and privilege, continues to permeate Western ideology (Foucault, 1972).

This linkage can be described as "psychological brutality," indicting the reproductive stratifying strategies of schools that lay down final judgments with no appeal, "ranking all students in a unique hierarchy of forms of excellence, nowadays dominated by a single discipline, mathematics, (Stinson & Bullock 2012). Here, to point the way to a mathematics education that might be more ethical and just, a case is made for considering postmodern theory (PT) in mathematics education. It is worth considering that that PT provides a means to make visible the Trojan Horse of the mathematics for all discourse, which, in turn, motivates different questions about and different possibilities for mathematics teaching and learning. (Stinson & Bullock 2012). Postmodernism rejects any static foundational system of logic; resulting therefore this study was unraveling the reality of the envisaged learner-centred mathematics pedagogy as against policy rhetoric.

**Statement of the Problem**

As already alluded to, the present mathematics syllabus requires teachers to adopt a social constructivist teaching approach, which includes problem solving, investigations, process skill development, applications of mathematics in local contexts, project work and course work assessment. These methodologies were and continue to be relatively new to most teachers and are also far removed from the absolutist classroom practices currently prevailing in Botswana (Rowell & Prophet, 1990; Prophet & Rowell, 1991; Prophet, 1995; Tabulawa, 1998, 2002).

There seemed to have an over expectation of teachers to implement the expectation the learner-centred teaching methodologies in the classroom despite their lack of knowledge on these methodologies. Teachers continue to frequently ask how learner-centred pedagogies manifest themselves in the classroom and many share a negative perception about postmodern education, which for them is an alien concept far removed from African classrooms where the teacher's task is best described as "*giving out and imparting school knowledge"* (Tabulawa, 1997:200). These perceptions and problems seem to have had a serious constraint on the successful implementation of the BGCSE mathematics curriculum with all its underpinning philosophical epistemological and anthological assumptions on teaching and learning.

**General objective**

The proposed research study described and analyzed both quantitative and qualitative successes and failures of implementing the postmodernist (social constructivist) education curriculum as espoused in the revised BGCSE mathematics syllabus.

**Specific Objectives**

The specific objectives of this study are:

- To assess the implementation of the learner-centred methods on BGCSE mathematics syllabus and to establish the impact of BGCSE mathematics syllabus implementation on educational outcomes.

- To explore teachers experiences on BGCSE curriculum implementation and to determine the impact of in-service training on the implementation of the learner-centred teaching methodologies.
- To assess new ideas presented in the syllabus as perceived by teachers and Critique the aims and objectives of the mathematics syllabus with the specific objectives in the syllabus.
- To establish professional development plan and support system was put in place to help teachers cope with the espoused postmodernist pedagogical approach to the BGCSE mathematics syllabus and to assess how has the BGCSE mathematics syllabus been operationalized in the classroom.
- Establish how the new ideas presented in the syllabus been perceived by teachers and to examine the reactions of students to the existing teaching methodologies.
- To establish how in-service training impacted on the implementation of the learner-centred teaching methodologies and to examine how the compartmentalization of the syllabus into ‘core’ and ‘extended’ parts impacted on the implementation process.

**The Research Question**

The central research question for the study is:

To what extent has the envisaged classroom implementation process of the BGCSE mathematics syllabus been achieved considering its postmodernist (social constructivist) methodological rhetoric?

- How consistent are the aims and objectives of the mathematics syllabus with the specific objectives in the syllabus (critique of the syllabus)?
- What professional development plan and support system was put in place to help teachers cope with the espoused postmodernist pedagogical approach to the BGCSE mathematics syllabus? academic
- How has the BGCSE mathematics syllabus been operationalized in the classroom?
- How have the new ideas presented in the syllabus been perceived by teachers?
- What are the reactions of students to the existing teaching methodologies?
- How has in-service training impacted on the implementation of the learner-centred teaching methodologies?
- How has the compartmentalization of the syllabus into ‘core’ and ‘extended’ parts impacted on the implementation process?

**The Research Hypothesis**

There is significant difference between the implementation of the learner-centred BGCSE mathematics syllabus and student performance thereof.

*Null Hypothesis*

There is no significant difference between the implementation of the learner-centred BGCSE mathematics syllabus and student performance thereof.

**The theoretical and conceptual framework**

The study investigated the process of implementation with regard to the BGCSE mathematics syllabus following the decision by Ministry of Education to localize the syllabus from the CUES. This requires some understanding of the process of curriculum implementation with specific reference to the social constructivist pedagogical rhetoric (i.e. *'leaner-centred methodology'*) which informed the localization process.

This study adopted the Goodlad, Klein &Tyle (1979) theoretical framework and used a typology of curricular representations to conceptually underpin the framework. This theoretical framework includes:

- ideal or intended curriculum (original ideas of the designers)
- formal curriculum (documents, materials)
- perceived curriculum (especially by the teachers)
- operational (actual instructional process in classroom)
- experiential (reaction and outcomes of the learners)

There was a careful study of these curricular representations with the aim of building detailed information on the situation surrounding the implementation process. The debate over postmodernism versus rhetoric illusion in education enjoys a long history. The purpose of this section of the paper was not to take a side in that debate, but rather to consider how mathematics education is envisioned in trying to reach desired outcomes and to situate this view within the range of possible subject organizations of the high school curriculum (Woodbury, 1998). At one end of the spectrum of curriculum organization and implementation possibilities is a subject-cantered approach, in which each subject is understood as discrete. An analogous description can be made of a high school mathematics curriculum where, for example, algebra, geometry, statistics, and business mathematics are taught as separate courses without an organized attempt to develop connections between the mathematical ideas that compose those courses.

At the other end of the curriculum implementation spectrum is full curriculum integration, in which the disciplines of knowledge are not used independently in the planning of learning activities, but are brought to bear as they become useful in problem solving situations. "Curriculum integration, in theory and practice, transcends subject-area and disciplinary identifications; the goal is integrative activities that use knowledge without regard for subject or discipline lines, (Beane, 1995.cited in Woodbury 1998).

It is also envisaged that the concepts of '*learner- centred methodology'*; '*core*' and '*extension'* parts of the syllabus which formed the curriculum implementation rhetoric were investigated with respect to their underpinning philosophies, how they were operationalized and hence, how they impinged on the implementation process.

The theories define the route of knowledge from basic to refined knowledge through logic. The environment always contributes as a factor in attitude modeling.

**The philosophy**

Scholars contend that the methodological choices researchers make depends on their philosophical assumptions about ontology, human nature and epistemology (Wright & Crimp, 1995; Spratt, Walker & Robinson, 2004) as well as the topic under investigation (Blumberg, Cooper & Schindler, 2008; Bryman, 2012; Babbie, 2015). Creswell (2014) defines research philosophy as a term that concerns the creation of knowledge and the nature of that knowledge (epistemology). Creswell (2014) further posits that an appropriate research philosophy will help with attaining research aims, purpose and objectives.

The philosophy that underpins my research is that of social constructivism. Constructivists view knowledge and truth as created not discovered by the mind (Schwandt, 2003). Social constructivism posits that the world we experience and the individuals we find ourselves to be are first and foremost the product of social processes (Cromby & Nightingale, 1999). It is my belief that there are multiple realities as each of us constructs our own reality and that there can be multiple interpretations of those realities.

The social constructivist paradigm was appropriate for my research project as it advocates that knowledge and activity are intimately related (Berger & Luckmann, 1991). This directly relates to my overall research that investigates the implementation of learner-centred education (LCE) in the mathematics classrooms based on teachers' understanding and beliefs. In essence, it explores how teachers' understandings of LCE are linked to their beliefs and how these beliefs eventually shape their practice. The social constructivist paradigm equally "assumes a relativist ontology (there are multiple realities), a subjectivist epistemology (knower and respondent co-create understandings), and a naturalistic (in the natural world) set of methodological procedures" (Denzin & Lincoln, 2005, p. 24).

My study aimed at examining the different ways teachers viewed LCE, observing how they practiced LCE and co-constructing meanings with them. I chose teachers as the focus of my study because implementation of any change in classroom depends "on those who work on a daily basis with learners taking ownership of new ideas and practice" (James & Pollard, 2011, p. 66). Teachers thus can be powerful agents of change (McKinsey, 2007).

**The design**

The study is a mixed method survey employing numerical quantification of data for possible generalisation as well as face to face interactions with informants for a direct discourse. The use of mixed method allowed the researcher to triangulate information gathered through various means. The use of both quantitative and qualitative approaches can occur at different points in the research process (Caruth, 2013; Creswell, 2011; Ponce, 2011). Mixed methods research (MMR) is a more complex method in response to the observed limitations of both quantitative and qualitative designs and became a valid alternative to either of the research designs.

It offers richer insights into the phenomenon being studied and allows the capture of information that might be missed by utilizing only one research design, enhances the body of knowledge, and generates more questions of interest for future studies that can handle a wider range of research questions because the researcher is not limited to one research design. It requires the researcher to be knowledgeable in quantitative, qualitative, and mixed methods designs (Caruth, 2013).

Scholars such as (Creswell, 2012; Gall, Gall & Borg, 2007; Greenwood &Terry, 2012) maintain that the intent for combining quantitative and qualitative research designs was to maintain the strengths and ameliorate the weaknesses in both designs. It is noted that the combination of quantitative and qualitative methods presents a more enhanced insight into the research problem(s) and question(s) than using one of the methods independently (Creswell, 2012; Frels & Onwuegbuzie, 2013; Hong & Espelage, 2011). If MMR is used, however, the researcher(s) must have a working knowledge of both quantitative and qualitative methods designs to effectively combine the methods. Hence, MMR is more advanced, time-consuming, extensive, and may necessitate the use of a research team (Creswell, 2012).

Some strengths of MMR design include using words, photos, and narratives to add meaning to numbers while numbers can add precision to words, photos, and narratives. MMR can handle a wider range of research questions because the researcher is not limited to one research design. Further, it offers enhanced validity through triangulation (cross validation) and can present a more robust conclusion. Cronholm and Hjalmarsson (2011) add that the use of MMR can increase the capability to generalize the results compared to using only quantitative or qualitative study designs.

The two designs are best used concurrently, but can be more time consuming and expensive. The use MMR requires that the researcher(s) learn multiple methods to combine them knowledgeably, defend the use of multiple methods, and utilize them professionally. However, MMR is not without conflict because methodological purists maintain that researchers should work within either a quantitative or a qualitative research design never mixing the two designs in a single study (Cronholm & Hjalmarsson, 2011).

As the implementation of the mathematics curriculum has been going on for some time now, this study was in a summative nature, taking on board all available formative evaluation documentation.

**The population**

The population comprised of 32 senior secondary schools in Botswana and a representative sample of 10 senior secondary schools were selected using random sampling with all mathematics teachers in the sample used as subjects of the study. Representative samples of schools were selected using mostly randomised selection techniques. Fifty teachers randomly selected were given questionnaires to complete and only 70% of the sample returned usable questionnaires.

An interview schedule solicited information on respondents about learner-centred method and student's response during teaching, 80% of the sample was interviewed and provided useful data. Sampling is very important in survey design especially when the problem to be solved requires a large population (Aina, 2009). Sampling techniques involve selecting an unbiased and representative sample whose findings can be used to generalize the whole population (Aina, 2009). Therefore, this study employed simple random sampling in selecting representative senior schools. This technique was chosen because it allows the researcher to draw a sample of schools which is representative of the population in terms of critical factors such as demographic location of various schools and regions. Then stratified random sampling was used to select schools within regions. Schools were grouped according to regions to enable representation across the country. Stratification produces a smaller error of estimation than would be produced by a simple random sample of the same size. The results are particularly true because measurements within strata are very homogeneous.

## Instrumentation

The study solicited information from both mathematics teachers and their seniors about the implementation of the BGCSE mathematics curriculum with a view to determine whether the learner-centred education approach envisaged by the curriculum designers has been achieved. Data was therefore, collected through questionnaires and interviews with Heads of mathematics departments in respective schools. There are basically two types of instrumentation models which are cross-section survey and longitudinal survey (Aina, 2009).

This study employed a descriptive survey research design to seek views of individuals, in this case, teachers from selected schools in Botswana. Cross-sectional survey has been adopted because it allows the collection of large amounts of data from a sizeable population in a highly economic way. Further, it is perceived as authoritative and is both comparatively easy to explain and understand. Data collected using survey was used to suggest possible relationships between variables. Surveys were structured with deductive approach, therefore, allowing data to be collected and analysed quantitatively using descriptive or inferential statistics. Data was obtained by administering questionnaires and interviews to a sample and the data was standardized, allowing easy compilation (Saunders, Lewis, & Thornhill, 2009). In view of limitations of the questionnaire in providing in-depth reflections, a semi structured interview was used on a small sample of senior teachers to complement the gap created by questionnaire. The questionnaires consisted of a number of phases some being; bio data of respondents such as age range, level of grade, gender, school attended and the region of the school; teacher compliance with a variety of teaching methods; open-ended questions on challenges encountered by teachers during a mathematics class; how learners respond to methods used during mathematics classes; enjoyment and motivation issues during class of mathematics and on heuristic approach as affected by learner's potential. This also assisted in obtaining clarity and immediate feedback and most importantly direct verbal interactions between the researcher and the respondents.

**Validation of instruments**

It was important to confirm that the instrument measured what it purports to measure and consider its consistency in measuring what it was designed to measure. The questionnaire incorporated existing validated scales constructed in collaboration with the research themes. The questionnaire included all the factors in the conceptual framework. To enhance the reliability and validity of the questionnaire, a pilot study was conducted on teachers and selected students from a school which was not part of the sample. The interview schedule included open-ended questions seeking the respondent's remarks and identification of possible ambiguities in the questionnaire. The researcher also requested the Supervisor and other university experts to check the reliability and validity of the instrument. This helped the author to check for the amount of systematic or built-in error in measurement (Creswell, 2013). In addition to that, the degree of consistency was measured using Cronbach's alpha coefficient, a measure of internal consistency that shows the degree to which all the items in a test measure the same attribute (Carnoy, Chisholm, and Chilisa, 2012). Cronbach alpha is used to estimate the proportion of variance that is systematic or consistent in a set of test scores. It can range from 00.0 (if no variance is consistent) to 1.00 (if all variance is consistent) with all values between 00.0 and 1.00 also being possible. For this study, the Cronbach alpha for a set of scores was .90, meaning that the test was 90% reliable, and by extension that it was 10% unreliable (100% - 90% = 10%). It is mandatory that assessors and researchers should estimate this quantity to add validity and accuracy to the interpretation of their data. It ensures that each test item measures the same latent trait on the same scale.

**Data**

The study was developed in 2016 and much of the data collection was carried out by 2017. In closed questionnaires, multiple answers were provided to allow respondents to pick one or as many options as relevant (Aina, 2009). In open-ended questionnaire, respondents were encouraged to express their views on several issues without any restraints. A number of reasons justify the use of questionnaire in this study. They include: it facilitates the collection of large amount of data in a relatively short period and it is also cheap to administer. An interview was also conducted in a safe place as suggested by participants and all appointments for interviews were made open to respondents. A semi structured face to face interview was considered as core. The interview was timed as per agreement with respondents to give enough time for direct quotations from respondents about their experience and opinions (Patton, 2002). The interviews involved taking of notes by the researcher and respondents had a portion to write their views guided by the researcher. Anecdotes were written by senior teachers on the implementation of the BGCSE mathematics curriculum with a view to find out whether the postmodernist social constructivist education approach envisaged by the curriculum designers had been achieved with desired effects.

### The analysis

Data analysis means a search for patterns in data re-current behaviours, objects or a body of knowledge (Neuman, 2007). It involved manipulation to presentation in some sort to general interpretation of its meaning or making sense out of the data. Since both qualitative and quantitative data were collected, several strategies were employed to analyse them. Descriptive statistics using tables, graphs, pie charts formed part of quantitative data analysis. Thematic analysis was used for qualitative data which was arranged in groups based on themes, concepts or similar features as guided by the research questions (Chaputula, 2009). Each research question was analyzed using a model of analysis that suits its intents. Statistical analysis applications like Chi-square descriptions were derived on independent variables; age with gender, position, academic qualification, years of teaching experience. The Chi-square assisted the researcher to decide on which variables depended on each other. Linear model (OLS) was also used to test for the significance between variables and to find the relationship between the dependent variable and the predictor variables. These were employed as appropriate for quantitative data and identifying themes and categories of emerging issues from the qualitative data.

### Discussion of findings

**Dependent Variable: performance**

| Model | | Unstandardized Coefficients | | t | Sig. |
|---|---|---|---|---|---|
| | | B | Std. Error | | |
| 1 | (Constant) | 35.377 | 2.998 | 11.800 | .000 |
| | learner_centred | .094 | .045 | 2.078 | .046 |

*How consistent are the aims and objectives of the mathematics syllabus with the specific objectives in the syllabus (critique of the syllabus)?*

*Table 1: Frequencies on how respondents answered questions*

**Statistics**

| | | student supervision(other than teaching) | student project supervision | what academic qualification or teacher training certificate do you have | do you use a textbook in teaching mathematics to your class | what subject matter do you emphasize in your mathematics class |
|---|---|---|---|---|---|---|
| N | Valid | 35 | 35 | 35 | 34 | 33 |
| | Missing | 0 | 0 | 0 | 1 | 2 |

This Function provides statistics and graphical displays that were used for describing many types of variables. Table 3 shows a sample on how teachers responded to the questionnaire and variables that were not addressed.

*Table 2: Teachers-Student project supervision*

| | | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|---|
| Valid | | 2 | 5.7 | 5.7 | 5.7 |
| | 0 Hour/Period | 25 | 71.4 | 71.4 | 77.1 |
| | 1 Hour/Period | 5 | 14.3 | 14.3 | 91.4 |
| | 2 Hour/Period | 2 | 5.7 | 5.7 | 97.1 |
| | 5 Hour/period | 1 | 2.9 | 2.9 | 100.0 |
| | Total | 35 | 100.0 | 100.0 | |

The above description suggests that the majority of mathematics teachers engaged less or never in student project supervision as advocated for by the mathematics curriculum in support of learner-centred model. For example, 25 (71.4%) indicated that they spent 0 Hour/Period on student project supervision, 5 (14.3%) engaged 1 Hour/Period on supervision, and 2 (5.7%) devoted 2 Hour/Period on student project supervision.

## Conclusions

This study was set to find out, to what extent has the envisaged classroom implementation process of the BGCSE mathematics syllabus been achieved considering its postmodernist (social constructivist) methodological rhetoric, it was also guided by the following general objectives:

- To assess the implementation of the learner-centred methods on BGCSE mathematics syllabus.
- To establish the impact of BGCSE mathematics syllabus implementation on educational outcomes.
- To explore teachers experiences on BGCSE curriculum implementation.
- To determine the impact of in-service training on the implementation of the learner-centred teaching methodologies.
- To assess new ideas presented in the syllabus as perceived by teachers.
- Critique the aims and objectives of the mathematics syllabus with the specific objectives in the syllabus.

- To establish professional development plan and support system was put in place to help teachers cope with the espoused postmodernist pedagogical approach to the BGCSE mathematics syllabus.
- To assess how has the BGCSE mathematics syllabus been operationalized in the classroom.
- Establish how the new ideas presented in the syllabus been perceived by teachers.
- To examine the reactions of students to the existing teaching methodologies.
- To establish how in-service training impacted on the implementation of the learner-centred teaching methodologies.
- To examine how the compartmentalization of the syllabus into 'core' and 'extended' parts impacted on the implementation process.

The main conclusion drawn from these findings is that lack of learner centred model of teaching mathematics contributes to poor performance in mathematics education. At this stage the study cannot suggest policy recommendations though conclusions and recommendations can be drawn from the study. Some literature review and theories of this study considering the findings contain some limitations which are ought to be mentioned.

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**Article 25**

# Causal factors and impact of workplace injuries on teachers' performance: The case of design and technology in Botswana.

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**Abstract**

Cases of workshop injuries on teachers in Botswana secondary schools have been reported. These injuries take place in Design and Technology (D&T) machine rooms and workshops during material preparation for students' practical projects. The causes of these injuries and their impacts on teaching and learning have not been investigated. This study was conducted to determine the causal factors of workplace injuries on teachers' and their impact in the teaching and learning of D&T in Botswana. A total of 30 report documents of cases from 2014 to 2018 were used as data source. A quantitative-descriptive perspective, integrating the Heinrich's domino model of accident causation was adopted as the research design. Data variables uploaded on SPSS included accident period, age of the injured, employment type, work experience, cause of injury, type of injury, causal agent, and condition of machine used. The majority (86%) of cases were found to have been caused by a combination of factors including the usage of underserviced machines, lack of protective equipment and inexperience. All the accidents occurred during the second term of the schools calendar year, a time leading to the final submission of the practical projects for assessment. Proposed recommendations include deployment of laboratory technicians as well as making scheduled regular inspection and frequent servicing of machines and equipment a policy issue.

**Keywords:** *Heinrich's domino model, Workshop injuries, occupational injuries, Causal factors, Practical project*

## Introduction

The Ministry of Basic Education in Botswana has employed over 3000 Design and Technology (D&T) teachers deployed in all secondary schools across the ten educational inspectoral regions. D&T activities present the highest levels of risk for injury to both teachers and students. It is therefore essential that the risk for injury associated with each D&T activity be identified, assessed and mitigation steps be taken to minimise injury at all costs. With the adoption of outcome based education (National Curriculum and Assessment Framework, 2015), it is imperative that practical activities requiring more 'hands on' learning experiences in D&T will increase, therefore exposing both learners and teachers to more hazards. According to Ezrailson (2013) an increase in the number of practical and workshop activities increases possibilities of injuries for both students and teachers.

Practical activities by students are carried out using material prepared by teachers from the machine rooms. Preparation in this case involves reducing large pieces of available stored material to sizable pieces that students can work with. The machine room is a room fitted with fixed immovable machines for material preparation and is normally out of bounds for students. Normally there are two large machines mounted in the machine room in junior secondary schools in Botswana. These machines are the Thickness Planer, which is used for planing and levelling of timber and a Circular Saw that is used for ripping and cutting down large boards and sheets of timber and plastics. Over the years, there has been several reports on teacher injuries suffered during material preparations in these machine rooms. The number of reported cases are so high to suggest that the teaching of the practical aspects of the subject could likely be impact negatively. The high number of incidents occurrence can be attributable to a number of reasons, including: negligence due to work pressure, usage of unserviceable and faulty machines, and unsafe use of the machines. The International Labour Organisation defined workplace related injuries as "an unanticipated and unplanned occurrence including acts of violence resulting from and in connection with work which cause one or more workers to incur a personal injury, disease or deaths (ILO, 2014, p 1).

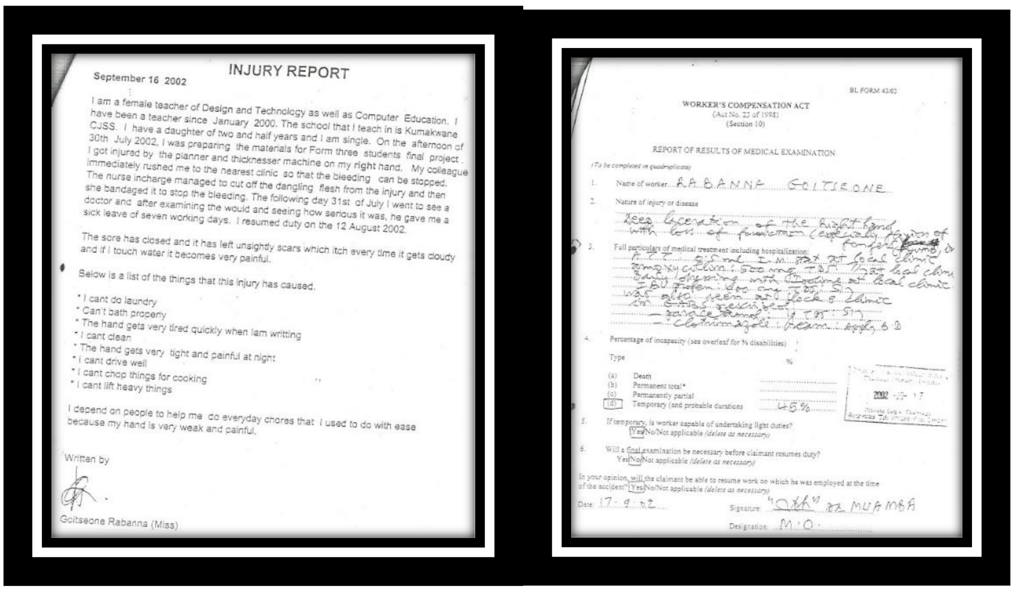
## Background

When D&T was first introduced in Botswana secondary schools in 1990, it was piloted in (16) junior schools and five senior schools (Moalosi, 2001). Now it is offered as an optional subject in every public secondary school. When it was first introduced in Botswana secondary school curriculum ''it was to replace the traditional technical subjects of woodwork, technical drawing and metalwork which were offered as independent disciplines'' (Moalosi & Molwane, 2008, p.27). D&T, and its philosophy has evolved over the years. Now it requires the use of modernised and scaled down equipment and machinery. The equipment used nowadays are smaller and more power controlled. Even though they are not as intimidating as the ones that were used in the past they are still extremely dangerous hence posing as serious hazards to those who use them. This has been the case in Botswana where reports on workplace injuries involving D&T teachers have been recorded over the years. This presents an image for the subject that may not be appropriate to both the learners and teachers. A lot has been done to present D&T as a subject that is suitable to both males and females as opposed to its predecessors which were viewed as masculine subjects. Occurrence of teacher workplace injuries in D&T may just work against the uptake of the subject, particularly amongst female folks.

Teacher's workplace injuries do not only affect those injured and those exposed to danger in their everyday working lives, but it also has a negative impact on the profession and the subject in particular. The trauma that teachers experience as a result of workplace injuries is a likely handicap. This affect the quality of education because traumatised teachers can hardly avail themselves to assist to their full potential when they have been rendered insecure by the machinery and teaching practises post the experience. According to Haynie (2008, p.97) Labs of today are less safe, the students of today are inadequately instructed in safety, and the teachers of today simply do not have adequate experience with equipment to lead students safely. Safety of teachers, safety of students, safety of laboratories and safe use of machinery and equipment in the D&T laboratories is a critical issue which must be addressed at all levels of technology education.

## Statement of the problem

Teacher's workplace injuries do not only have an impact on their health and wellbeing. Oftentimes teachers are left traumatised, handicapped and demotivated. The education of students is also interrupted when injured teachers take time off from work to recuperate from injury after accidents. The following are examples of records of teacher's workplace injuries that occurred during material preparation in the D&T machine rooms in schools in Botswana.



September 16 2002

INJURY REPORT

I am a female teacher of Design and Technology as well as Computer Education. I have been a teacher since January 2000. The school that I teach in is Kumakwane CJSS. I have a daughter of two and half years and I am single. On the afternoon of 30th July 2002, I was preparing the materials for Form three students final project. I got injured by the planner and thicknesser machine on my right hand. My colleague immediately rushed me to the nearest clinic so that the bleeding can be stopped. The nurse incharge managed to cut off the dangling flesh from the injury and then she bandaged it to stop the bleeding. The following day 31st of July I went to see a doctor and after examining the would and seeing how serious it was, he gave me a sick leave of seven working days. I resumed duty on the 12 August 2002.

The sore has closed and it has left unsightly scars which itch every time it gets cloudy and if I touch water it becomes very painful.

Below is a list of the things that this injury has caused.

* I cant do laundry
* Can't bath properly
* The hand gets very tired quickly when Iam writting
* I cant clean
* The hand gets very tight and painful at night
* I cant drive well
* I cant chop things for cooking
* I cant lift heavy things

I depend on people to help me do everyday chores that I used to do with ease because my hand is very weak and painful.

Written by

Goitseone Rabanna (Miss)

BL FORM 43/03

WORKER'S COMPENSATION ACT
(Act No. 23 of 1998)
(Section 10)

REPORT OF RESULTS OF MEDICAL EXAMINATION

*(To be completed in quadruplicate)*

1. Name of worker: RABANNA GOITSEONE
2. Nature of injury or disease: Deep laceration of the right hand with loss of function (especially [illegible] of fingers) [illegible]
3. Full particulars of medical treatment including hospitalization: [illegible]
4. Percentage of incapacity (see overleaf for % disabilities)

Type | %
(a) Death
(b) Permanent total*
(c) Permanently partial
(d) Temporary (and probable durations) 45%

5. If temporary, is worker capable of undertaking light duties? Yes/No/Not applicable *(delete as necessary)*
6. Will a final examination be necessary before claimant resumes duty? Yes/No/Not applicable *(delete as necessary)*

In your opinion, will the claimant be able to resume work on which he was employed at the time of the accident? Yes/No/Not applicable *(delete as necessary)*

Date: 17 · 9 · 02  Signature: [illegible] MUAMBA

Designation: M.O.

2002 -10- 17

Figure 1. *Teacher injury report*

Figure 2. *Photographs showing teacher injuries*

## Purpose of the study

The study was carried out with the purpose of identifying factors that contribute to the occurrence of injuries on D&T teachers' in the school machine rooms. As well as establish the impact of these injuries on teaching and teachers wellbeing. So the following research questions were used to guide the study.

1. What factors contribute to the occurrence of injuries on D&T teachers' in the school machine rooms?
2. What impact has these injuries have on the teacher's performance in the workplace?

## Significance of study

While D&T by its nature exposes teachers and learners to workplace injuries due to practical activities requiring more 'hands on' learning experiences, the area of workplace injuries remain undeveloped and under researched. The study explored the causal factors that leads to the occurrences of teacher injuries in the D&T machine rooms, thereby contributing valuable knowledge worthy of consideration in the development of D&T curricula. Safety and First Aid is a common theme in D&T curricula, but the coverage does not go beyond the dangers and safety precautions. It is important to start a conversation of the impact of these injuries on the outlook of the subject and this study is significant as a source of reference for further research in this area.

## Literature Review

Over the years, with the evolution of the education system the teaching profession has become more difficult, more demanding, frustrating at times for teachers and even more dangerous. Teachers work tirelessly to help improve their students' academic achievement. Working under a lot of pressure for a teacher is a hazard on its own since they risk being involved in workplace accidents. According to (Chinchilla, 2002, as cited in González, Bonilla, Quientiro, Reyes & Chavarro, 2016. p.5)

'Workplace accidents can result from immediate or basic causes; the immediate causes directly produce the accident and are composed of unsafe acts (inappropriate behaviour of the workers) and unsafe conditions (facilities, equipment, machinery and tools that are faulty). But to achieve an effective solution to occupational accidents, it is critical to identify and control the basic causes which result in the immediate causes; they include personal factors (incorrect work habits, incorrect use of equipment, tools or facilities; physical or mental defects, hearing deficiencies, etc.) and work factors (deficient supervision and leadership; unsuitable policies, procedures, guides or practices; unsuitable work planning or scheduling'

In their occupational injury analysis study González, et.al (2016) discovered that there are three causal factors that highly contributed to workplace accidents and injuries. That most of the workplace accidents that occurred were as a result of loss of control and unsafe acts where employees do not observe some safe practises ending up being involved in accidents. The second factor was age as they discovered that younger workers were mostly affected as they lacked experience and were unaware of the hazards they were exposed to. The third cause was workers personal factors relating to their abilities.

Gyekye (2010), reckons workplace accidents can be attributed to two fundamental causes; internal and external causal factors. Internal causal factors relates to the characteristics and the personalities of the worker whereas the external causal factors relates to the characteristic of the environment of the workers.

According to Osang, Obi and Ewona, (2013), occupational accidents occurring in science laboratories and workshops results in workers losing their lives and some get injured as a result of ignorance, neglect or carelessness. Dolan (1979) also observed that too many victims have been claimed by workshop accidents. Dolan noted that of the reported cases in his analysis, approximately 70% of the accidents were due to neglect on the part of workers.

Uwaifo (2009) argues that it cannot be denied that whenever there is a workshop with machines installed and tools placed for people to use as they work, then the possibility of accidents occurring will always be there. However, it is important that measures be put in place to either eliminate or at least reduce such accidents, because these accidents have a negative impact on the productivity of the individual involve and consequently on the whole organization.

One of the greatest concerns of occupational safety researchers is to understand the causal factors that contribute to the occurrence of accidents (Alizaheh, Mortazavi, & Sepehri, 2015). There has been a number of studies carried out looking at aspects like the training offered, exhaustion due to working overtime, the age of the workers injured, the length of service and the most important factors that causes the occupational accidents. According to Alizaheh et.al. (2015) they include Personnel factors such as age, gender, experience, Environmental and equipment factors such as cause of injuries, severity and type of injury, Project factors such as the type of work being done, the amount being done and finally the management factor such as the company size, support and provision of safety equipment and training provided by the organisation.

Battaglia, Feyes and Passetti, (2014) argues that looking at the workplace injuries from the eyes of the worker, injuries in the workplace causes a lot of pain and suffering. Firstly, it affects the injured person's family life style in terms of dealing with the psychological trauma caused, the injuries obtained and the cost and time of treatment. The injuries reduce the physical capacity of the injured person and makes them insecure of their capabilities at the workplace. From the eyes of the employer (Battaglia et al., 2014) argues that workplace accidents that results in employees injured can have a negative effect on the organisation. That it reduces production and most likely cause increased insurance pay-outs as injured workers should be compensated.

According to Mehmood, Maung, Consunji, Menyar, Peralta, Al-Thani, and Hyder (2018), workplace injuries are likely to cause death amongst those involved. They do not only produce a likelihood of fatalities but they can also lead to disabilities. Workplace injuries also decreases productivity in the work area since injured workers will have to take some time off to recuperate, it also leads to the loss of skilled manpower, observed Mehmood et al., (2018). In a case where a highly trained individual is injured, taking time from work means replacement for production to go on and in most cases they are replaced with temporary employees who might need to be trained to diligently continue with the work that was being done.

In agreement with Mehmood et al., (2018), Rahim and Wong (2017) observes that workplace accidents that occurs usually results in injuries, limb disabilities and even to some extent loss of life. This in most cases tarnishes the image of the institution. Training institutions are supposed to be equipped to effectively allow students to acquire the necessary skills and knowledge and more emphasis should be placed on safety measures to ensure the level of risks and hazards is drastically minimized.

Safety is a condition of being safe from harm. According to (Garcicia-Herrero, 2012), safety in the work environment is observed in order to create a suitable work station that can allow workers and organisations to work safely, with limited risks and or hazards. Safety requires that the conditions put up as safety measures should alleviate possibilities of occurrence of hazards that can render employees unfit to carry out their tasks at the workplace. Jonathan and Mbongo (2016), argues that safety in the workplace is such a legitimate concern. To guarantee safety for the teaching staff in schools, there should be proper maintenance of all the available equipment that teachers use in their teachings. Kassa (2015) reckons that in order for an employee to have a strong knowledge on practise, working safely and prevention of workplace injuries then they should have a positive attitude. Patrick and Adejuyigbe (2013) agrees and argues that an attentive person with a positive mind-set and a positive attitude is able to ensure absolute control when working. That absolute control of the machinery with diligent operation minimises the risks that can occur. The moment the safety aspects are abandoned it will probably result in accidents that can cause injuries, fatalities and even damage to property around.

D&T workshops and machine rooms are high risk areas and they should be taken as such at all times. Hall and Marsh (2003) reckons that the staff working in the workshop area should not only focus their concerns on the possibilities of students getting injured but should also protect themselves so that they could reduce the chances of them being injured while working as well. While it is true that these workshops and machine rooms are high risk areas, everything possible should be done to present them differently just so that future potential Designers, Technologists, and Engineers do not find their way elsewhere.

## Methodology

This study was conducted within a quantitative-descriptive perspective, integrating the Heinrich's domino model of accident causation (Heinrich, Petersen, & Roos, 1980). Heinrich saw the occurrence of a "preventable injury" as the culmination of a series of events that form a sequence, similar to a row of dominos placed so that the toppling of a first domino knocks down the next, which makes the third fall down, and so on until the entire row is toppled. The most important policy implication in this case would be to avoid toppling any one domino which in turn would prevent the accident from occurring.

The scope of this study was documentary. The source of data and the unit of analysis of the study were the documented reports (n=30) of occupational accidents that occurred from 2014 to 2018 and registered with the Botswana Sectors of Educators trade union (BOSETU). The office of Safety, Health and Environment at BOSETU provided the reports for purposes of this study. The following real life data was extracted from the documented reports and uploaded on SPSS for easier management of the data: date, causal agent, age, gender, part injured, condition of the machine and severity of injuries. According to Bowen (2009) analysing documents is a form of research where documents are interpreted by the researcher to give voice and meaning around an assessment topic. Document analysis are stable, "non-reactive" data sources, meaning that they can be read and reviewed multiple times and remain unchanged by the researcher's influence or research process (Bowen, 2009, p. 31).

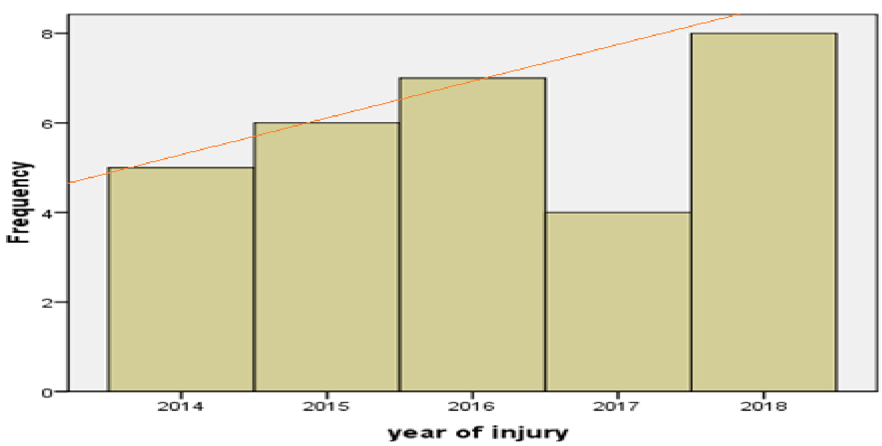
**Data analysis**

The general understanding and interpretation of machine room injuries was obtained using descriptive statistics. SPSS version 16 was used to analyse the association between the factors influencing the cause of the injuries as accidents outcome.

**Findings and discussions**

The finding indicates that over the period under investigation there was a steady increase of accidental injuries recorded from 2014, 2015, and 2016, then there was a decline in 2017 and then a sharp increase of 50 % in 2018. Generally, despite a decrease of reported injuries in 2017 the results present an increasing pattern of reported accidents as shown in table 1.

**Table 1: Frequency of the workplace injuries by year**




This increasing pattern of reported injuries should be a course for concern given the fact that not all injuries are reported for different reasons. Taking note of impacts and effects of injuries on teachers' performance and the trickledown effect on learner achievement the ideal situation and the intention of this study is to have a pattern that shows decreasing occurrences of injuries. If this pattern is left to replicate then the outlook of D&T will continuously drop, with uptake and performance also declining as has been the outcry (Gaotlhobogwe, Laugharne & Durance, 2011).

Demographic characteristics of the reported injury cases indicated that most accidents occurred among teachers in the early years of their career. A study by Hanvold, Kines, Nykänen, Ólafsdóttir, Thomeé, and Holte, (2019) reports that young employees are at greater risk of occupational injuries as compared to their older co-workers. Young employees lack the experience, patience and takes more risks in carrying out some experiments as part of their explorative nature, the study reports. Alizadeh, Mortazavi and Sepehri, (2015) also agrees with their frequency distribution of experience confirming that young workers (< 35 years old) suffer occupational accidents due to their lack of experience, arguing that risky behavior is generally influenced by age whereas working experience increases more with age. As shown in Table 2 the majority of cases were recorded among teachers aged between 31-35 (43 %) followed by those aged between 25-30 (30 %) and then 36-40 (20 %). whereas there was none recorded for those aged between 41-45, and only 2 (7 %) was recorded for those aged between 46 -50. While it may be perceived that perhaps the majority of teachers in the system may be those in the early years of their career, the occurrence of injuries to these groups is likely to affect their performance in the future. They are likely to develop resentment and fear of machines and thereby compromise their duty. However, this group is also likely to be susceptible to injuries because of lack of experience in handling these machines, but impact on performance is the same, resentment and fear.

**Table 2: Demographic characteristics**

| Age* (yr) | Number (%) | Gender | Number (%) |
|---|---|---|---|
| 25–30 | 9 (30) | Male | 27 (90) |
| 31–35 | 13 (43.3) | Female | 3 (10) |
| 36–40 | 6 (20 ) | | |
| 41–45 | 0 (0) | | |
| 46–50 | 2 (6.67) | | |

The results indicate that of the 30 reported injury cases 27 involved male teachers, and only 3 female teachers. The gender imbalance was not unexpected because secondary schools and training institutions are experiencing a low enrolment of female students in D&T as compared to their male counterparts. However, it must also be noted that majority of female teachers already have some form resentment and fear of these machines. Due to this resentment and fear coupled with cultural upbringing, where there are male teachers available female teachers would leave material preparation to the male teachers under the pretext that operating machinery is a masculine job. Should these views go on unabated, the underrepresentation of females in the subject would continue into the future.

With regard to causal agent, condition of the machine and injured part of the body, the finding are presented in Table 3. All the reported injuries were caused by a circular saw. Generally, there would be two machines in the machine room, these being a Thicknessor or planner, and a Circular saw (see Figure 3). The Circular saw seem to be the most dangerous because its blade is mostly exposed while that of a Thicknessor is concealed. That notwithstanding, a Circular saw has an attached safety guard that should always be in place when the machine is in use.

**Table 3: Causal agent, condition of the machine, part injured**

| Causal agent | Number (%) | Condition of machine | Number (%) | Part injured | Number (%) |
|---|---|---|---|---|---|
| Thicknessor/planner | 0 (0) | Serviced | 4(13.3) | hands | 17 (56.7) |
| Circular saw | 30 (100) | Not serviced | 26(86.7) | fingers | 13 (43.3) |
| Tools/equipment | 0 (0) | Safety guards attached | 7(23.3) | face | 0(0) |
| | | No safetyguards | 23(76.7) | legs | 0(0) |

As indicated in Figure 4 % of the victims indicated that the machines they were using at the time of injury were not serviced while 77 % indicated that the machines they were using had no safety guards. The machines used in the schools were first installed when the schools started operation in the late 1980s so a lot of them are very old and some are faulty. Injuries recorded were sustained to the hands (57 %) and to the fingers (43 %). Probability of injuries to the hands is very high in the case of an accident occurring because the control of the movement of the materials during cutting is done using one's hands. However, the safety precautions when using a Circular saw recommends that a push stick be used when the handling is closer to the cutting blade. Studies show that most of the hazards encountered when using a circular saw was due to the absence of the safety guard which covers the blade as it cuts. Improper built and mounting of safety guards which in turn fail to give the intended protection was also shown as a common safety issue. Scheduled regular inspection of machines is a normal safety measure put in place to prevent accidents. These regular inspection exercises are non-existent in schools in Botswana.

**Figure 3: Image of a circular saw**

Table 4 presents findings regarding severity of injuries and the time [in months] during in which the injuries occurred. 67 % of these injuries were very serious, 20 % were moderate and 13 % were severe resulting in amputations of fingers. All the injured needed serious medical attention after the injuries with the 13 % of the severely injured being hospitalised for operations. All were given time off from work to recuperate and they needed regular check-ups with their doctors to monitor the healing progress of their injuries. All this cost them their teaching time and it affected them financially in that they needed to settle their medical bills and cover their transport fees for their frequent visits to the doctors. The month of July recorded more accidents at (37 %) whereas May recorded the least accidents at (13 %). The months indicated in Table 4 fall under the second term of the schools calendar year, a time leading to the final submission of the practical projects for assessment.

Clearly the time leading to final submission of projects for assessment is the time that students should not lose their teachers to workplace injuries because they need their teacher's support and guidance in preparation for final examinations. So the time off taken by the injured teachers either to go for medical attention, to recuperate, and for hospitalization impact negatively on the academic achievement of students. Boden, Elyce and Emily (2001) established that workplace injuries have got a noticeable impact in the workplace. According to (Boden et.al, 2001) workplace injuries do not only have economic implications but it affects the employer, the affected employee, their families and other staff members. That it delays production in the workplace and affect the psychological wellbeing of those involved.

**Table 4: Severity of injuries, time in which injuries occurred**

| Severity of injuries | Number (%) | Injury time months | Numbers (%) |
|---|---|---|---|
| Minor | | May | 4 (13.3) |
| Moderate | 6(20 ) | June | 9 (30) |
| Serious | 20 (66.7) | July | 11 (36.6) |
| Severe | 4 (13.3) | August | 6(20) |

It must be noted that the time leading to the final submission of the practical projects for assessment is a period when teachers are working under pressure to get their students through the realization stage of their projects.

## Conclusion and recommendation

Despite the fact that D&T activities present the highest levels of risk for injury to the both students and teachers, and that cases of workshop injuries on teachers have been reported in Botswana secondary schools, this has remained the least attended area in research and in policy. There is no available literature on workshop injuries in the D&T, however, this study has indicated the impact that these injuries have on the subject, and on the teachers and students alike. The absence of scheduled regular inspection of machinery in schools in Botswana is a clear indication that safety has not been accorded the attention it deserves in the education policy, but this needs to change. The findings presented in this paper are pointing researchers, policy makers, curriculum designers and developers to this area of workshop injuries as requiring attention because of its impact on different aspects of the subject. Based on this conclusion, the following specific recommendations are proposed:

1. Laboratory technicians need to be deployed in junior secondary schools' workshops in Botswana and one of their duties be material preparation. In this way teachers would be relieved of the task of material preparations and thereby no or less risk of teacher injuries.
2. Scheduled regular inspection of machines should be made a policy issue.
3. Frequent servicing of machines and equipment used in the D&T workshops should be made a policy issue.
4. There should be a SHE (Safety, health and Environment) officer appointed in schools and or clusters of schools so that they could assess and monitor hazardous and unsafe conditions in the workplace and in the process prevent accidents from occurring.

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**Article 26**

# Facilitating STEM education for vulnerable school children through library outreach: The children centre linkages

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**Abstract**

The school library as a setting for learning STEM offers opportunities for informal learning especially for public primary school children who are vulnerable in Nsukka Locality. The Children's Centre Library (CCL), through its support from other NGOs has extensive outreach programmes for the class teachers, school librarians, and school pupils of more than 30 primary schools for STEM learning. The general question that this paper seeks to answer is, in what ways do school libraries facilitate STEM education for vulnerable school children? In order to address this question, the involvement and experiences of the Children's Centre volunteers who have facilitated STEM education in schools through library outreach was looked into. An exploratory interview was used to gather data from ten (10) library professionals who are involved in organizing workshops, facilitating outreach programmes and developing new programmes. From the responses gathered and coded, it was deduced that the Children's Centre has consistently facilitated the learning of science, technology, engineering and mathematics in their various capacities. However, from their experience, it implies that if the class teachers, school librarians, school management, educational policy makers and in fact all, do not work together, STEM learning may not be fully realized.

**Keywords:** *STEM education; vulnerable children; Primary education; Children Centre linkages*

## Introduction

This study seeks to provide a report on the school library as a vehicle for facilitating science, technology, engineering and mathematics (STEM) education in primary schools. Our report is informed by two interrelated factors that brought about the school library to limelight: the limited time for the study of STEM in the school timetable which has challenged the incorporation of variety of learning resources by classroom teachers, and second, the need to explore various learning spaces other than the formal classroom environment to build creative skills in the learners. While the classroom has been a basic place when it comes to realizing STEM education, there is persistent far cry on the lack in skills development in schools which has led to increase in the number of those who are unemployed; thus bringing about "a mismatch between the outputs of the educational systems and the needs of the job market" (EL-Deghaidy, et al, 2017) and as indicated by the 2016 National Bureau Statistics (Longe, 2017), leaving 52 million citizens within the economically active population of Nigeria jobless. The Australian Education Services (2018) holds a prediction that over the five years to 2022, education and training will be among the largest jobs growth while a lot of STEM education research reveals that facilitating STEM education in primary schools positively influences later involvement in STEM disciplines in more advanced levels of learning (EL-Deghaidy, et al, 2017; Australian Library and Information Association (ALIA), 2017; Education Department, USA, 2016; Baek, 2013).

Children naturally are creative and need to be provided with an ideal setting and atmosphere to nurture STEM engagement activities suitable for their age. By vulnerable school children, therefore, we mean children whose schools are not privileged to have benefited from library development and varieties of resources for STEM education. Proof from experts in Library and Information Science concerning school library as a setting for learning STEM abounds (ALIA, 2017; IFLA, 2015); thus, guiding learners to exhibit high abilities and competencies to address the dynamic world will develop information literacy skills needed for various aspects of learning, including STEM learning (Onyebuchi and Ngwuchukwu, 2013; Dike, Ngwuchukwu and Onyebuchi, 2010).

This study reports the involvement of the Children's Centre Library (CCL) of the University of Nigeria in organizing programmes and learning resources for public school libraries for STEM education in primary schools.

## Background

Children's Centre Library was born in the late 1970s out of the desire to create learning environment to children within the university environment http://www.childrenscentreunn.org. Located in the University of Nigeria, the centre has recognized the objective of developing libraries to reach out to unprivileged set of schools that are impoverished regarding their libraries. CCL, being a voluntary project of the University of Nigeria Women Association (UWA) has gained support from other NGOs such as the People's United for Libraries in Africa (PULA), a foreign non-governmental organization that tries to reach out to unprivileged set of schools that may not have benefited from library development, Iwuanyanwu Foundation and the Parents' Teachers' Association (PTA) of each school and other governmental and non-governmental agencies (World Bank assisted project through the Universal Basic Education (UBE) and Educational Trust Fund (ETF) (Dike, Ngwuchukwu and Onyebuchi, 2010).

The library opened as the first component of the project on October 17, 1978. The initial funds came from the University Women's Association (UWA) and Nigerian Association of University Women (NAUW), Nsukka Branch, with accommodation provided by the Department of Health and Physical Education. Activity programmes began with a Children's Festival in the International

Year of the Child, 1979. Chief E. C. Iwuanyanwu also offered to build the permanent facility, dedicated in 1986 in loving memory of Madam Hulder Iwuanyanwu. By 1988 the mutual relationship between Children's Centre and the then department of Library Science was formalized. (http://www.childrenscentreunn.org)

The library has engaged in various activities on school library development (Dike and Amucheazi, 2012-13; Ngwuchukwu and Onyebuchi, 2013). Programmes offered include creative arts, science and technology, environmental awareness, sports, and other areas.

## Missed Opportunity

The need for building skills for critical, innovative and lifelong thinking in children to facilitate their learning of STEM has been emphasized in the educational philosophy of the Nigerian National Policy on Education (FGN, 2014) and its significance has been intensified by the far cry for effective participation in the society. Nonetheless, normal classroom environment presents a challenge for imparting these skills creativity and innovative, with classroom activities characterized by drill and recitation, copying of notes; passive learning and in effect, teachers non proactive spirit. How then can pupils build their skills in a situation like this through STEM learning?

It becomes an issue of concern to the professional librarians to find alternative ways of facilitating the learning of STEM through creative and innovative programmes available in the school libraries. To this end, Moomaw and Davis (2010) warn that for STEM education to have the desired effect of developing both individuals' lifelong learning skills and potentials for sustained interest in STEM topics and issues, STEM learning should be fostered in children through different educational pathways; and one way of facilitating this is through the use of the school libraries.

Thus, the Children's centre library is poised to facilitating STEM learning across Nsukka Educational Zone

## Research Questions

In what ways do Children Centre Library, UNN facilitate STEM learning for children in public primary schools?

1. In what ways does Children Centre Library facilitate STEM learning in classrooms, in the school library and in the community?
2. What benefit have you recorded through the Children Centre Library linkages
3. What challenges have you encountered through the outreach programme of the Children's Centre

## Methods

A purposive sample of 10 professional librarians from a volunteer team of 23 university women was selected to participate in the interview study. Two reasons influence the choice of the sample size: first, the fact that these selected group where actively involved in school library development;

and therefore, would be in a better position to provide information on CCL and STEM education. Second, the limited time for recruiting, scheduling conducting and analyzing the data realized from the interview. Many observations, experiences, challenges and best practices of this group could be an example of how CCL contribute to STEM learning.

The participants for the interview were recruited from Children's Centre Committee WhatsApp forum, a forum for the sharing experiences of the volunteers (http://www.childrenscentreunn.org). Six (6) of them work with the department of Library and Information Science, three (3) work with Nnamdi Azikiwe Library, University of Nigeria while one (1) has retired and is presently involved in non-governmental organization. Librarians in this sample have provided learning activities for seven years on average, with a range of five to twenty years. Using a semi-structured interview schedule (see Appendix), the librarians were asked about their involvement in CCL. All interviews were conducted in August, 2019. One-on-one contact was used for participants who were disposed while phone-in was used for those who were not readily available for a visit. The time for the interview ranged between 45 and 60 minutes. The quotes were coded in RA - RI (Where R represents Respondent and A- I represents the serial letters of the ten (10) professional librarians selected for the study. Results gathered from the interview were analyzed in narratives with the provision of quotes where necessary. These quotes are deemed necessary because professional librarians who are experts in school library development are in the best position to explain how the school library setting is suitable for academic and skill development in general (Maxwell, (Baek, 2013).

**Analysis and Findings**

The responses gathered from these areas are incorporated in the answers given to the research questions.

**Research Question 1: In what ways does Children Centre Library facilitate STEM learning in classrooms, in the school library and in the community?**

Librarians highlighted that the Children Centre Library facilitates STEM learning through their involvement in the programme as library professionals. A respondent recounts:

*My interest is to contribute to practical learning of STEM in schools especially in science, and technology…so, it really touched my sympathy and interest to ensure that these children get basic knowledge of Science and technology. ($R^B$)*

Individuals in the group have worked as volunteers in the Children Centre library ranging from ten (10) to forty-five (45) years. The most senior among them had this to say:

*Arriving at UNN in 1975, I soon joined two women's groups, the Nigerian Association of University Women (NAUW, limited to graduates) and University Women's Association (UWA, for all female staff and staff wives) ($R^A$).*

These were books and other information resources meant to develop knowledge, skills, and values in school children's education and STEM learning in particular. Thus:

*STEM education is therefore not seen as a thing apart or something emphasized at the expense of the arts and social sciences but part of a whole fostering creativity, the humanities and ethics which ground STEM in the basic issues of life and society and CCL has been a place providing materials for both scientific and technological discovery and exploration of all fields of knowledge ($R^A$).*

***Children's Centre Resources***

Respondents described their role in terms of STEM learning as an attempt to bridge the gap between traditional classroom STEM learning and STEM learning through library support in schools.

*We have concentrated more on science and technology, as a look at the shelves will show. This is also true of books we have donated to schools ($R^H$).*

One respondent had this to say:

*Our projects in local schools have always been aimed at promoting reading, developing programs to teach information literacy, and developing school libraries. ($R^A$).*

In addition, the Children Centre volunteers organized learning activities for the school children to ascertain maximum use of library resources for voluntary reading club including stem related materials *'like Professor Dike's 'Birds of our land', from 2009 to 2017' ($R^C$).*

***Children's Centre Vacation Programme***

The Children's Centre plays a crucial role in STEM learning during the vacation programme

*'among these are activities fostering learning skills, car maintenance, agriculture, health, safety, cookery, sewing, crafts like tie-dye and hat-making, and more recently, computer education' ($R^A$).*

One of the respondents recounts how volunteers achieve this:

*We map out vacation period workshop… we do the programming, we invite bicycle repairers to teach pupils repair of bicycle, all the parts of the bicycle and all what those parts do with their locomotion. They learn how to do that and when they get to their homes, they do it. For the girls, we teach them mainly areas of home keeping…these are all science related areas ($R^B$)*

And so:

*CCL children grow and develop skills. For instance, activities like building block, we are producing building engineers. In doing that we are directing their mindset to what these children want to be ($R^F$).*

***Organizing Workshops for Teachers***

The Children's Centre has also carried the teachers and school librarians along in the promotion of STEM learning through workshops and trainings:

*Children's Centre has facilitated STEM learning through training initiatives for literacy in all forms and information literacy in particular, through workshops for teachers (use of library resources, let's find out, project work, story hours, cataloging, etc.) in local schools ($R^A$).*

Another respondent recounts:

*The Head Teachers, class teachers and school librarians have been participating in school library workshops because they find it useful ($R^B$).*

***Children's Centre Projects in Local Schools***

Most the services and activities of CCL are directed towards increasing STEM learning outcomes for vulnerable children in Nsukka and beyond. Thus, according to a participant:

*Children's Centre has been very useful and educational. We teach them mathematics and teach them various levels of computing and figures and they are very smart ($R^B$).*

School children are trained to develop skills for better participation in the society. These skills are achieved through hands-on engagement. And as one respondent explains;

*Such programmes like tailoring, soap making, shoe making, woodwork, bead making, designing, building (game), counting, and other examples of such programme ($R^G$).*

The children's Centre volunteers are poised to making pupils engage in different activities that will attract them to use the school libraries. Thus, as a respondent stated;

*In a project by Onyebuchi on 'Developing library period programme for teaching information literacy skills in Nsukka' in 2010, a programme for teaching various skills of lifelong learning was designed ($R^A$).*

It was recorded from one volunteer that the centre visits the Pharmacy Department, the Engineering Lab Motor Engine parts, *'…we have a girls' STEM club where we discuss science related subjects and issues. For instance, last time, we discussed about Engineering and the girl-children reacted to it' ($R^C$) and… 'I have been in the team managing ICT related issues in CCL e.g. Face book, website, and WhatsApp, trying to disseminate information concerning CCL activities. We teach them creativity, science & technology, for the world to see through these media' ($R^H$).*

Most of these activities are made visible as encouragement to other professional librarians as well as a sign that where there is a will; there is a way.

**Research Question 2: What benefit have you recorded through the Children Centre Library linkages?**

Children Centre Library have recorded success in their school library services and programme through different linkages they have established. Thus, one of the respondents states:

*We have had groups donating books, like public libraries in U.S., PULA (People United for Libraries in Africa) especially for school library development in 2005-2007. Government agencies like Nsukka LGEA, working with education officers Anthonia Ugwu and Grace Okoro; Enugu SUBEB (had library week activities), UBEC workshops of World Bank-Assisted Primary School Library Project about 2000-2002, and NERDC ($R^A$).*

In line with this, a respondent reveals:

*We have so many linkages: we have the professors, lecturers who work in the Children's Centre. The department of Library and Information Science has a statutory linkage with the Children's Centre which is recognized by the university authority as a lab where a lot of activities related to STEM are carried out. ($R^A$).*

Reiterating further on this, another respondent recounts that '*the centre has had continuous donation of science books, graphical resources, and comics with different science, engineering & innovative backgrounds from PULA and other organization for the promotion of STEM learning in the community and schools around' ($R^I$).* A responding volunteer gives an account:

*We have also partnered with different association (e.g. International Association of School Librarianship, Nigerian School Library Association, Nigerian Library Association) in carrying out our programme to schools in notable days of recognition like the World Book Day, World Literacy Day to organize hands-on STEM programmes ($R^G$).*

These groups check back on the progress of the CCL with regards to literacy development and skill-based activities. Another responding professional stated that these groups would always get feedback through a network, 'e.g. *international exchange programme… some Fulbright fellows to come and teach the pupils…in STEM related areas' ($R^B$) and 'Competition can be organized in Mathematics, computer, etc. where STEM has to come in ($R^J$).*

**Research Question 3: What challenges have you encountered through the outreach programme of the Children's Centre?**

The area, generally being dominated by middle class families and other low-income earners, the respondents reacted to the challenges that inhibit the services CCL for STEM education:

*Parents hardly buy voluntary reading materials for their children. In the reading club I run, I photocopy books and other reading materials for them ($R^C$).*

Others recount that, '*STEM and other curriculum modules are not implemented in classrooms. For instance, science curriculum has examples of hands-on learning, use of resources, experiments, but these are crowded out by stress on rote learning, lack of materials, or lack of knowledge on the part of teachers' ($R^E$).* Worse still, on implementation of the library period in the school curriculum, '*Where schools have some kind of library, library periods to provide learning opportunities and access to resources in spite of recognizing need' ($R^A$), 'Personnel quality is* *going down, plus undervaluing of teachers librarians (neglected, job not valued, not consulted)' ($R^A$); 'Consequently, those books we were instrumental to organizing in their libraries especially scientific and technology resources, were kept under lock and keys, with no pupil consulting them' ($R^C$).*

Volunteering is one factor that is greatly affecting the services of humanity generally. As some respondents put it; '*People don't fancy voluntary activities especially because there is no payment attached; coupled with the work load in the profession' ($R^J$)*; '*Volunteers hardly come by and recruiting new volunteers is a problem since not all have passion to serve' ($R^B$).*

On what they have to say, one of the respondents, shares:

*I see the children's Centre filling a gap in Nsukka community in their teaching and learning because of the volunteer force. We produce students who would continue in volunteering ($R^{\mathbf{D}}$)*

**Discussion**

In an attempt to answer the research questions, the researchers looked into the activities of the Children's Centre with regard to STEM learning both in the centre, in the classrooms and school libraries; within the children centre and its environment and beyond. Data collected showed that the engagement in STEM education and development has always been a part of the Children's Centre objectives.

**Children Centre Library and STEM learning**

Facilitating STEM learning is one of the utmost priorities of the Children's Centre (http://www.childrenscentreunn.org). The first set of analysis viewed the Children's Centre Library's science and engineering related activities, innovative and skill-based services and programmes in STEM learning in the centre, in classrooms, in the school libraries and in the community at large. This is in line with Todd who posits that "school libraries are powerful agents of learning that enable the transformation of information…in an information and technology-intense world" (2012; p2).

Children's Centre resources and vacation activities have yielded positive results from the CCL angle, aimed towards developing their knowledge for sciences, technological application, engineering abilities and critical thinking such as tailoring, soap making, shoe making, cookery, woodwork, repairing, bead making, designing, building (game), puzzles, counting, traditional games e.g. 'Ncholoko', and much more. Further, different programmes have been developed with the aim of fostering pupils' information literacy skills, entrepreneurship skills and academic development (Onyebuchi, 2010, Onyebuchi, 2018) which STEM is part of. To this end, the volunteers have organized pupils' training, excursion, library visits, reading clubs and STEM clubs to help realize lifelong learning abilities in pupils.

### Children Centre Library and Linkages

Findings from the volunteers indicate that Children Centre Library has work directly or indirectly with various groups to see to the facilitation of STEM education. These groups have the shared vision with the Children Centre: for and commitment to learning and teaching (Price, 2004), reading promotion and skills development. Such groups are NGOs (PULA), Nigerian government Agencies (National Education Research and Development Council, Abuja; Nsukka LGEA, Universal Basic Education Council; SUBEB) Department of Library and Information (University of Nigeria) Association Associations (IASL; NSLA; NLA, Enugu state) and foundation (Iwuanyanwu Foundation) and Individuals (Alumni). Thus, this is in concurrence with Handelsman & Sakraney (2015) who stated that the engagement of stakeholders plays crucial roles in facilitating STEM learning in area. As an organization facilitated by a group of library professionals who are volunteers, the Children Centre needs support in various ways in order to effectively carry out the task of STEM development.

### Push-backs of CCL in STEM Education

Findings show that the roles of school libraries in schools are neglected. Some of the challenges include the fact that teacher-librarians are seen to play dormant role in school; lack of interest on the government and school management, closing down of some school libraries after being set up; difficulty in the part of the government to enforce the implementation of library period in the school timetable or implementation of developed school programme/curriculum. Using a developed programme for information literacy in primary schools has not been considered (Onyebuchi and Ngwuchukwu, 2013; and Dike, Ngwuchukwu and Onyebuchi, 2011) for effective STEM realization.

### Children’s Centre Library: The Good news!

In an attempt to overcome some of the challenges of realizing library mission and vision, some best practices are adopted while some are still on the pipeline. First, library period programme has shown efficacy through students’ research and projects carried out. Second, professional associations have advocated for incorporation of library period in timetable. Third, CCL personnel have worked with officers, head teachers, teacher-librarians and class teachers on local level; advocated for personnel through members’ membership in professional associations; giving them career ladder so they will stay in profession. Better still, the volunteers are passionate about finding alternative ways to facilitating STEM activities in school; with school libraries open or not through reading promotions, literacy activities, the World Book Day programme, the STEM club, the reading club, the vacation programmes, the trainings and workshops, the exhibitions, the excursions, and other activities that are constantly organized for schools and school children. The Children’s Centre therefore is poised to maximizing opportunities to create learning environment for innovative, creative, technology-based, critical thinking and lifelong learning of school children especially those in public schools.

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**Article 27**

## Difficulty in syllabus objectives interpretation of junior certificate science syllabus

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**Abstract**

The study investigated how school based continuing professional development (SBCPD) contribute to the effective interpretation of science syllabus objectives by teachers for the Junior Certificate Science Syllabus. The study was conducted in six (6) Junior Secondary Schools in Kgatleng Region, Botswana. Syllabus objectives are drawn based on the curriculum. The Teacher is key in the implementation of the curriculum and must be able to interpret syllabus objectives more effectively. The current Junior Certificate Science syllabus for Botswana has been implemented since 2010. A survey research design was used for the study. A total of twenty two (22) respondents being science teachers participated in the study. The region has 40 integrated Science teachers. Questionnaires and Interviews were used to generate the data which was analysed using excel. The findings generally reveal that majority of the respondents are challenged in effective interpretation of some of the syllabus objectives and there was low school based continuing professional development activities. The study will create a reference base for similar studies to be conducted. It will also inform in-service department on areas of focus for Continuing Professional development for science teachers.

**Key words**: *Science, Syllabus, interpretation, objectives, Curriculum, Continuing Professional Development*

### Introduction

Teaching is dynamic. The changes in the environment where teachers operate affect their practice. The changes in the profession include relevant knowledge and skills which are affected by advancing technology, globalisation of education and the complex nature of the teaching and learning process. These conditions and developments require an improved emphasis on continuing professional development (CPD) among educators within and beyond (Sahagun & Matriano, 2019).

Botswana education system is a 3 tier system comprising seven (7) years of Primary education, three (3) years of Junior Secondary education and two (2) years of Senior Secondary education. Each year at Primary level is a standard and each year at secondary level is a Form. This system was implemented in 1995 as a result of a 1993 National Education Commission study. The commission's findings led to the formulation and adoption of the Revised National Policy on Education of 1994. It is the mandate of the Ministry of Basic Education to run the education system. The Ministry of Basic Education also emphasises on developing diversified curriculum to lay foundation for the market needs. One of the subjects in the curriculum is Integrated Science which is offered in the 3years of Junior Secondary School level. Mosothwane (2014) states that the current status of Science Education in Botswana Primary and Secondary Schools is based on the Revised National Policy on Education of 1994, Vision 2016, Education For All (EFA) goals and Millennium Development Goals (MDGs). Vision 2016 ended in 2016 and Botswana has drawn Vision 2036 which together with Sustainable Development Goals (SDGs) now guide the education system. Botswana has also developed Education and Training Sector Strategic Plan (ETSSP) which guides transformations in the education system. Botswana produces qualified teachers with three year Diploma in Education from Colleges of education and those with Bachelors' Degrees from University of Botswana. The teacher's understanding in interpreting and implementing the curriculum is of great importance. This role of the teacher must be enhanced by CPD activities which can assist the teacher to plan and implement more effective lessons. Botswana uses the cascade model for capacity building. Inservice activities take place at Educations Centres as opposed to at school level. There are limited SCBP activities which has contributed to teachers not being able to effectively interpret some syllabus objectives. Inservice activities especially that are school based are important to improve pedagogy which in turn promotes better learner performance.

**Statement of the problem**

There are limited School Based Continuing Professional Development activities for teachers. This has contributed to teachers not being able to effectively interpret some of the Science syllabus objectives.

**Objectives of the research**

1. Evaluating the structure of the Junior Secondary School Science Syllabus
2. Analysing factors considered by teachers during lesson planning
3. Evaluating the role played by In-service system with emphasis on School Based Continuing Professional Development

**Significance of the study**

The study will provide a knowledge base for further research by teachers and guide Integrated Science teachers on improving Curriculum interpretation skills and School Based Continuing professional development for effective classroom practice that can improve learner performance in the subject.

## Methodology

Mixed Method was used. Quantitative data was collected using questionnaires and qualitative data was collected using group interviews.

The study targeted Integrated Science teachers in Junior Secondary Schools in Kgatleng Region, Botswana. The sample was drawn from 6 Junior Secondary Schools out of the 10 Junior Secondary Schools in the region. Factors of proximity of the schools to the researcher motivated the selection of the schools. The schools were coded using number 1 to 6. The Study had a total sample population of 22 respondents being practising Integrated Science Teachers. This was purposive sampling. The population was representative as the total number of Integrated Science Teachers in the region was 40.

Questionnaires and group interviews were used to collect data. Questionnaires using likert scale which had mostly close-ended questions and one open-ended question were devised and self-administered to the participants. An interview schedule was devised and group interviews were conducted by the researcher in all the 6 schools. Data from questionnaires was analysed using excel and graphs were plotted. Data obtained from open ended questions in interviews was analysed by coding and grouping common issues.

## Literature review

How we conceptualise the curriculum and curriculum design is important because of the impact of these conceptions on the way we consider, think and talk about teaching and learning. (Stefani 2009).

Ben-Peretz M. and Kartz S. C (1982) state that teacher education in the art of curriculum interpretation is a strategy for engaging teachers and student/teachers reflectively in one of their professional activities, namely, making educational sense of curriculum materials. Su (2012) states that Educators and teachers are concerned about what choices are to make about teaching content and methods. Su goes further to state that Curriculum seems to be considered greatly as what teachers are going to teach and, in other words, what learners are going to learn. This indicates that they need a clear understanding of the curriculum so that they can plan and deliver effective lessons. In conceptualising curriculum Su goes on to state that Curriculum can be seen as a means of achieving specific educational goals and objectives. The emphasis on objectives is the characterisation of an objectives curriculum model. Botswana Integrated Science syllabus is in the objectives curriculum model. For teachers to be able to effectively interpret the curriculum they must be involved in its development. Alsubaie (2016) states that in order for curriculum development to be effective and schools to be successful, teachers must be involved in the development process. This is the case in Botswana. The panel on development of the current Integrated Science Syllabus comprised teachers.

The concept of basic education as per UNESCO ISCED[11] classification, Basic Education comprises Primary Education (first stage of Basic Education- ISCED level 1) and lower Secondary Education (second stage of Basic Education- ISCED level 2). Despite this Ministries of Education use the concept of basic education in quite different ways. In Botswana it is 10 years (Georgescu, Stabback, John, Ag-Muptah and de Castro 2008).

Effective curriculum interpretation at Basic Education Level helps learners to acquire relevant skills needed for the world of work and general life. Hattingh and Fraser (2013) state that the intended curriculum is to be interpreted and implemented by the educators who work at classroom level. They further state that South Africa however, is not alone in experiencing problems with the implementation of a new curriculum, and especially of technology education. Botswana Integrated Science Syllabus was implemented from 2010 and performance in the national examination has been consistently low.

Hattingh and Fraser (2013) alluded that successful implementation of any curriculum relies on the competency of the educators who are the agents practicing and implementing it in the classroom. Berkens, Van den Akker and Bryman (2014) state that the teachers lack of understanding of the curriculum/ teaching visions (teaching rationale/reasons) and goals in teaching a curriculum is becoming a worldwide challenge that needs to be addressed in order to promote quality teaching and critical thinking. Khoza (2015a) alluded that one of the curriculum or teaching visions which is personal vision creates an environment that helps teachers and learners to construct their own unique individual identities. This helps learners to construct knowledge and take a form of personal meaning.

Continuing professional development (CPD), before known as continuing professional education (CPE), is described as lifelong education of professionals on specialised knowledge, skills, attitude and moral values after the initial registration and admission to the profession. It is expected to raise and enhance the professional’s technical skills and competence required and expected by the stakeholders and the profession (Metz and Tharenou, 2001).

CPD is practised across the globe. Africa’s education systems are no exception as evidenced by the establishment of Strengthening Mathematics and Science Education in Africa (SMASE-Africa), a Pan-African organisation registered in Kenya (SMASE- Africa, 2018). One of the activities of SMASE-Africa is to promote teacher capacity development programmes. SBCPD programmes are part of the capacity development programmes. Botswana is affiliated to SMASE-Africa and her teachers benefit from the programmes.

In principle effective professional development (PD) leads to improved teaching and in turn, improved learning (Sahagun and Matriano, 2019).

The High-achieving education systems around the world are those capitalising greatly in the learning and professional development (CP) of their teachers. It is through this good quality professional development that real improvements in teaching and attainment take place (Sahagun and Matriano, 2019).

A number of studies have been conducted on the curriculum and curriculum interpretation in Botswana. In the literature review there was indication that most studies were not directed to Junior Secondary School Science level. This gap motivated the researcher to undertake the study to investigate if Integrated Science Teachers were able to effectively interpret the curriculum or syllabus objectives and if there were SBCPD activities in order to plan and deliver lessons that can produce the learner aspired by Botswana Junior Secondary Science curriculum.

**Findings**

A total of twenty six (26) questionnaires were distributed to practicing Integrated Science teachers in 6 Junior Secondary Schools and 22 were returned giving a response rate of 84.6%. Three areas were investigated and the findings were that:

**1.1.The views of teachers on the structure of integrated science syllabus**

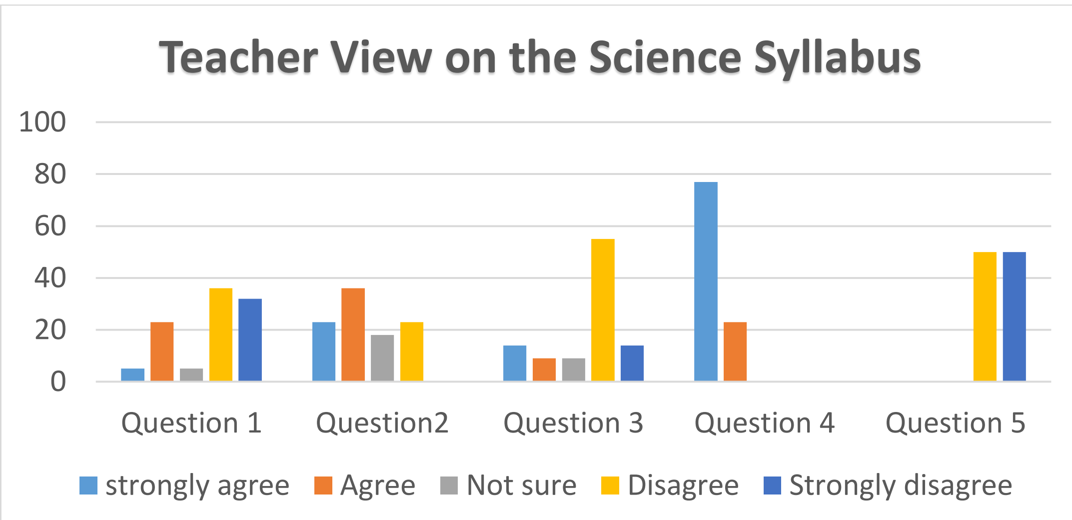


*Figure 1: The percentages of responses of teachers as per the 5 point likert scale.*

From the results in the graph above;

- 68% show objectives cannot be completed in the 3 year period
- 59 % show some objectives are repetition of what is covered in the upper primary syllabus
- 69% show that not all objectives are easy to interpret
- 100% show that the syllabus is congested
- 100% show objectives do not allow enough time for revision before national examination

**1.2. What considerations are made by teachers during lesson planning**

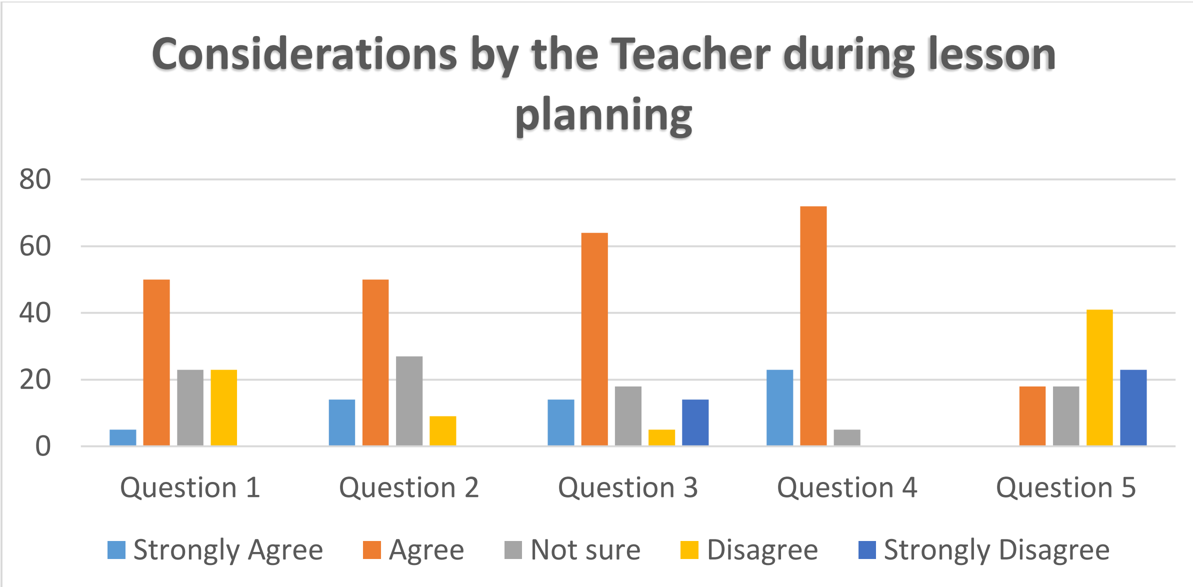


*Figure 2: The percentage of teachers' responses as per the 5 point likert scale*

From the information obtained, it was evident that:

- 55% understand the type of learner the curriculum aspires for
- 64 % consider the experiences of the learner
- 78% cater for expected learner responses
- 95% consider relevance of teaching-learning materials
- 18% show that facilities allow for effective planning and lesson delivery

**1.3. What is the condition of the teacher and the role played by in-service**

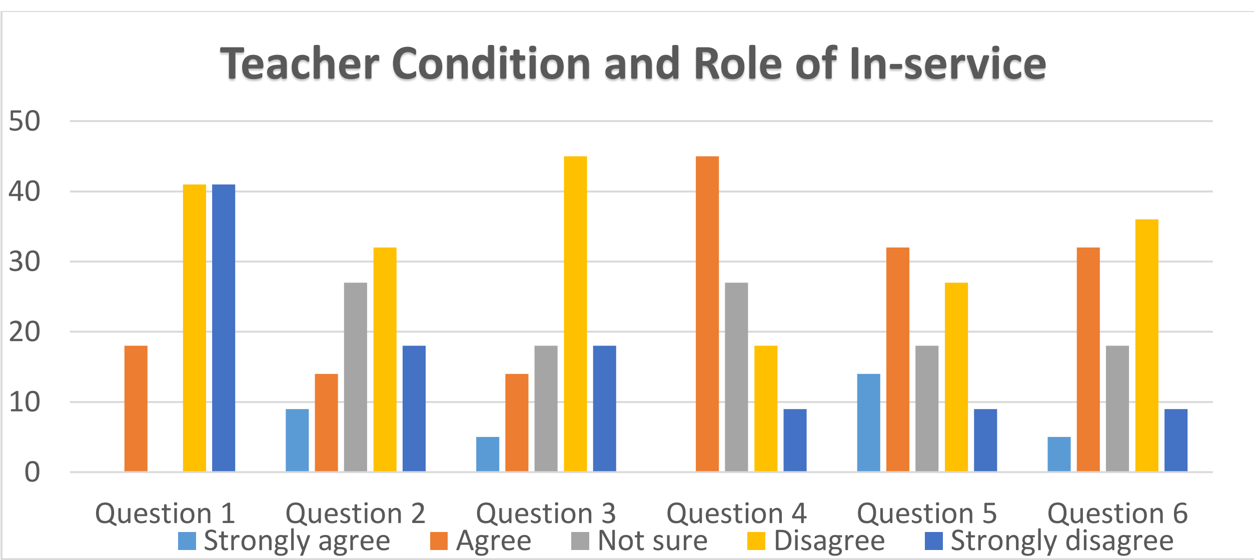

*Figure 3: The percentage of teachers' responses as per the 5 point likert scale*

From the information obtained, it was evident that:

- 82% show there is no planned termly SBCPD activities
- 23% show In-service activities planned help teachers grow professionally
- 19% show most Inset activities are School Based
- 45% show most Inset activities are conducted at Education Centres (27% not sure)
- 46% show there is inconsistent collaboration by teachers
- 37% show that Inset assist teacher to be innovative

**1.4. Thematic areas for analysis of quantitative data from group interviews**

**(i) Interpretation**

The responses are that most objectives are suitable for the Junior Certificate science level, even though they are congested and some are above the level of learners. Teachers are able to consider the kind of learner the syllabus aspires for, the learners' experiences from lower level and daily life.

Teachers are able to consider the relevance of teaching-learning materials and condition of Teaching- learning facilities are considered during planning. These are aligned to interpretation of the syllabus; however, the results indicate teachers have a challenge in interpreting some of the objectives.

**(ii) SBCPD**

Most Teachers were not trained in school based in-service, no school based in-service activities were conducted, hence no records kept. There were no formal collaboration activities at subject level. Teachers indicated that they determine the flow of the lesson.

Teachers were indicating they are more responsible for their Continuing Professional Development as they know their challenges best. Teachers cry foul of shortage of scientific equipment and materials to use in the teaching and learning process

**Discussions**

The results on the area of Teacher view on the Science Syllabus reveal that it is congested and cannot be completed in the three (3) year period. This in turn does not allow teachers and learners enough time for revision before the national Junior Certificate Examinations. The design of the curriculum is important so that its goals can be achieved.

The second area was to analyse factors considered by teachers during lesson planning. The respondents show understanding of the type of learner aspired for by the curriculum. Botswana

Government (2009) Three Year Junior Secondary Education aspires for a learner that has developed critical thinking, problem solving ability, individual initiative, creativity, interpersonal and inquiry skills.

Teachers were aware that they must consider experiences of the learner in relation to the objectives of the lesson. This will help probe learners' critical thinking. Botswana government (2015) Education Training will contribute to the achievement of overall education at different levels such as at individual level. This is by helping learners maximise their potential through a commitment to excellent teaching that demonstrates up-to-date pedagogy and by providing all learners with required skills and knowledge needed to succeed in Botswana society. These can be attained if the teacher is able to interpret the curriculum and plan lessons that will probe learners' critical thinking.

The facilities being science laboratories do not allow for planning and delivering lessons more effectively as most are not functional. The role the teacher can play is to be innovative and improvise. Kapur (2018) states that within schools it is vital to make provision of resources that can be utilised to enhance academic performance of students. Maganga (2016) as quoted by Kapur states that in science subjects, when the teacher is providing training to students regarding the implementation of the experiment through making use of test tubes, burners, equipment and procedures, then it is not possible for teachers to go to each and every student and check how, he or she is performing, this notion supports what respondents display as not enough facilities to allow planning and delivering lessons effectively. The respondents also indicate that learners perform more experiments and student-teacher ratio be reconsidered.

The third area on the survey was to evaluate condition of teacher and the role of in-service and findings reveal that there are little or no science aligned in-service activities conducted at school level. Most teachers are also not trained on School Based Continuing Professional Development and there were no records on Continuing Professional Development in all sampled schools.

Kapur (2018) states that the teaching-learning methods and strategies should be appropriate and encouraging to students. Methodology advocated for in Botswana Junior Secondary Science Syllabus is learner-centred. The School Based Continuing Professional Development approach will assist teachers grow professionally and deliver effective lessons which are learner-centred and produce the kind of learner aspired for by the curriculum. This can be achieved more so teachers are aware that they are more responsible for their continuing professional development. Exposure of teachers to the system will help them grow professionally.

## Conclusion

There are no School Based Continuing Professional Development activities which could allow Science teachers to formally collaborate on matters of effective classroom delivery, and in turn keep records of such. Teachers are therefore not able to effectively interpret some syllabus objectives and cope well with insufficient facilities in the form of Science laboratories hamper discovery learning in teaching-learning process. Large class size and high teaching loads also have input in pedagogy being not very effective.

Integrated Science teachers in Kgatleng Junior Secondary Schools are well trained in their subject of speciality. Most are aware of the kind of learner aspired for by the curriculum. They are also aware that experiences of the learner and relevance of teaching-learning materials must be considered during lesson planning. However, there are some gaps which hinder their practice to be more effective. These factors affect effective classroom delivery and learner performance include congested syllabus which does not allow revision before national examinations. Some objectives are a challenge as teachers are not able to effectively interpret and plan well for them.

## Recommendations

a) There is need to train teachers more on curriculum interpretation.
b) School administrators and Department of Basic Education- In-service must collaborate to promote School Based Continuing Professional Development (SBCPD). This will close the gap between pre-service and in-service. School Based Continuing Professional Development will also inculcate innovation amongst teachers to address shortage of materials and equipment needed for science teaching-learning process.
c) Recommendation is made for department of curriculum development and evaluation to revise the current Integrated Science Syllabus as it is congested.
d) Infusion of Information and Communication Technology in Science teaching-learning to improve pedagogy is recommended. This will also promote 21st Century learning.
e) The teaching load and Student-teacher ratio for integrated Science need to be revised with the idea of providing a platform where a teacher can have a more manageable class size.

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**Article 28**

# An assessment of Strengthening Mathematics and Science Education- In-Service Education Training (SMASE INSET) on teacher effectiveness and pupils' participation and academic performance in mathematics and science education in Nigeria

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**Abstract**

This study assessed the impact of SMASE INSET on teaching and learning of mathematics and Science Education in Bauchi and Oyo states of Nigeria. To elicit information from SMASE trained teachers and their pupils, and non-SMASE trained teachers and their pupils. A lesson observation check-list to determine the quality of teaching skills, the ASEI/PDSI lesson observation checklist to determine the degree of usage of ASEI\PDSI and pupils participation questionnaire to determine the level of participation of pupils were employed. SMASE trained teachers did significantly better than the Non SMASE trained teachers in the implementation of the ASEI strategies and PDSI approach. Pupils of SMASE teachers also demonstrated higher participation. The mean score of group 1 is 3.4408, 3.2281, and 3.2237 as against 2.8828, 2.4583 and 2.6719. Findings also indicated challenges and areas of difficulty like higher order thinking skills, teaching of graphs, indices, place value, magnetism, basic electricity and electrical circuit, etc. It is recommended that another INSET Cycle be initiated by the center as intervention for the gaps and challenges identified, Government to provide more support and strengthen SMASE INSET especially at school level and scale up the impact study to the remaining states.

**Key words**: *Assessment, impact, teacher effectiveness, pupils' participation, Academic Performance, in-service, training*

## Introduction

Technological advancement is fundamental in development of nations. From a global point of view, it is commonly recognized that the improvement of science and mathematics education is one of the key factors for country development (JICA, 2011). That explains why many countries strive to advance in science and technology. This desire is however, unattainable without a strong STEM (Science, Technology, Engineering and Mathematics) base which begins at the basic education level through the way mathematics and science subjects are taught and learnt.

Kontagora, Watts & Allsop (2018) posited that effective teachers play a crucial role in pupils' interest and performance.

In 2005, the Federal Ministry of Education (FME) Nigeria and Japan International Cooperation Agency (JICA) conducted a baseline study on the status of Mathematics and Science in selected primary schools in Nigeria. The study revealed that schools were facing serious challenges in teaching/learning of mathematics and science. The teachers engaged themselves in chalk and talk strategy while learners were passive participants in the classroom. (SMASE -Nigeria Project Document, (2005). The result of the study also confirmed a strong association between low teaching capabilities and poor learning performances. This low achievement in science and mathematics disciplines became worrisome and source of concern to parent, educators and government because science and mathematics occupy a special position for national development. This created the need to as a matter of urgency establish a mechanism to address the challenges of teaching and learning of mathematics and science subjects.

SMASE INSET also known as SMASE Nigeria Project was born out of the need to re-establish a strong system of re-training for in-service teachers in the areas of mathematics and science known as ASEI/PDSI (activity-based, student-centered, with experiments and improvisation/plan-do-see-improve) approach. The approach has been employed by Japanese teachers for ages and have proved very effective at building teachers' capacities and improving interest as well as performance of learners to develop critical thinking and problem-solving skills.

Based on the findings of the baseline study in 2006 FME and JICA piloted SMASE 3-tier INSET in three states in Nigeria- namely: Kaduna, Niger and Plateau. The themes of SMASE INSET Nigeria project cycles 1-3 could be broadly classified into three: i. changing attitude of teachers, ii. planning and delivering better ASEI lessons and iii. actualization of ASEI/PDSI Lesson. A mid-line impact evaluation study was conducted in 2008 which revealed a huge success recorded in both teaching and learning of the subjects. Those trained through the 3-tier INSET training were found to be using the ASEI/PDSI approach to replace the chalk and talk method. Consequently, the SMASE INSET was scaled-up to the remaining 33 states of Nigeria plus the Federal Capital Territory (FCT) From 2010 to date. Approximately 23,000 teachers have been trained through the cascade system, remarkably, there has been no study conducted after the mid-line impact evaluation study conducted in 2008 to ascertain the level of progress achieved with SMASE INSET and challenges being encountered.

**Statement of the Problem and significance**

Research evidence is very important and useful in situation analysis, setting objectives, measuring progress and even decision -making; most times in Nigeria research is relegated to the background in the scheme of things. Where it is employed at all, there is a huge gap for its demand. The urgent need to conduct another study in order to assess the impact of SMASE INSET and ASEI/PDSI usage in teaching and learning of Mathematics and Science in Nigerian primary schools is ardent. This study will provide an opportunity to scientifically assess the implementation of ASEI/PDSI principles, SMASE INSET achievements made, the challenges and gaps in implementation, it will also help to provide data that could be used to address the challenges identified and chart a way forward.

Accordingly, this study was built upon two previous studies: the 2005 baseline and the 2008 impact survey conducted by the FME and JICA.

**Aims and objectives**

This study has three broad aims and objectives which center around discovering the impact of SMASE INSET on teachers of science and mathematics, the impact of SMASE INSET on pupils' participation and interest is science and mathematics and areas of challenges.

Specifically, the study seeks to:

1. investigate and document the extent to which teachers that passed through SMASE INSET use ASEI/PSDI in teaching mathematics and science
2. document the factors that facilitate and inhibit the processes of ASEI/PDSI use in teaching and learning mathematics and science
3. determine the most effective levels of intervention necessary for the implementation of ASEI/PDSI in teaching and learning of mathematics and science

**Research Questions**

- To what extent do teachers use ASEI/PSDI in teaching mathematics and science?
- What factors facilitate or inhibit the use of ASEI/PDSI in teaching/learning mathematics and science?
- What are the most effective levels of intervention necessary for the implementation of ASEI/PDSI in teaching and learning of mathematics and science?

**Literature review**

**Teaching and learning of Science and Mathematics Education in Nigeria**

Science and Mathematics Education are disciplines that are concerned with training on the transmission of scientific and mathematics concepts mainly acquainted with questioning, experimenting and thinking. Moreover, mathematics and science education are abstract in nature which cannot be easily understood using traditional teaching methods of 'talk and chalk'. The National Commission for Colleges of Education (NCCE, 2002) stated that teachers ought to explore several methods of teaching for effective teaching and learning to be achieved. Science and Mathematics educators have attributed several causes of poor achievement among Nigerian Students in science and mathematics, these include student's inability to understand and apply science and mathematics concepts, poor quality instruction and lack of professional teachers (Dike and Ndokwo, 2007). Researchers have found that conventional practices such as lecture method and expository approach have scarcely proved that capability of giving the desired learning outcomes among students (Umoren & Aniashi, 2007, Atomatofa, 2013).The National Policy on

Education (2014) emphasizes paradigm shift in educational practices from teacher to learner centeredness, so as to enhance conceptual learning in science and mathematics and the development of positive attitude towards learning of science and mathematics. However, the desired paradigm shift is only achievable if the capacity of teachers in mathematics and science is developed, especially at the basic level of education, thereby transferring the requisite skills to pupils at their basic level of education. The search for alternative but viable option led to the exploration of instructional strategies based on ASEI-PDSI.

As a result of the shift, conventional practices of teaching are now in vogue.

**Strengthening Mathematics and Science Education (SMASE) Project**

Strengthening Mathematics and Science Education (SMASE) Project was born out of the dire need to improve the quality of Mathematics and Science education for national development (SMASE Nig. Project Doc. 2005). Hence the SMASE project have the dual goal of upgrading teaching skills of primary school teachers in mathematics and science as well as upgrading capability of Nigerian primary school pupils in mathematics and science.

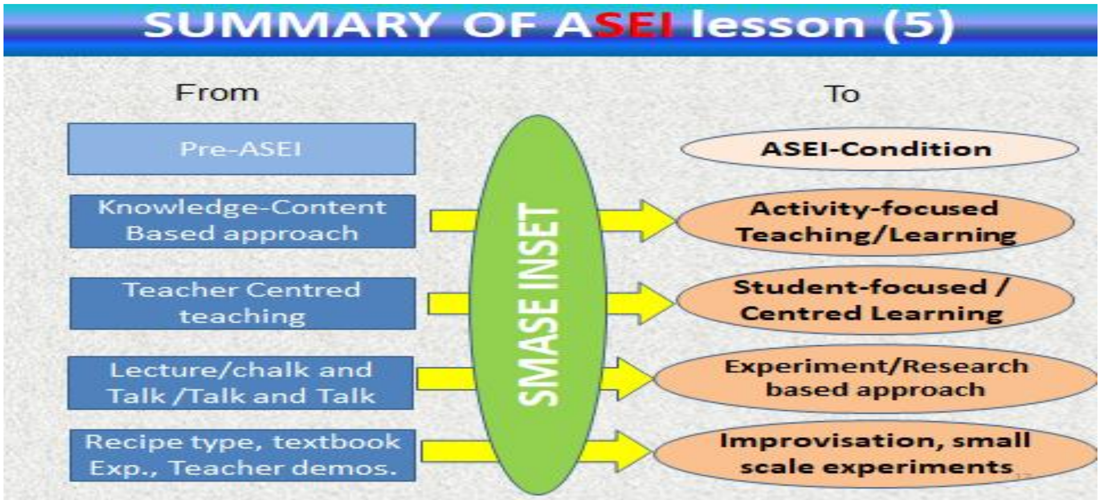
The main characteristics of SMASE project among others are focusing on In-service Education Training (INSET), where it addresses improving quality of teachers in terms of attitude, pedagogy, mastery of content, resource mobilization and utilization of locally available teaching materials. Another characteristic of the project that is upheld is the ASEI-PDSI approach. In this instance, it aims to shift teaching paradigm from "banking style/chalk and talk" teacher-centered to ''ASEI and PDSI'' learner-centered approach. The INSET runs in three cycles (cycles 1, 2, and 3).; each cycle lasts for two weeks. Cycle 1 addresses the issue of positive attitude towards teaching generally and mathematics and science in particular. Cycle 2 focuses on enhancing classroom activities for effective teaching and learning. Cycle 3 dwells on actualization of the ASEI-PDSI approach in the classroom. (JICA/FME, 2006)

It is organized on a three tier (National, state, and local) cascading system and school based training. The National trainers train 13 to 15 state trainers, the state trainers cascade to 200 core teachers at the state level and the core teachers train 600 teachers at the local level, who subsequently take the training to school level. SMASE Nigeria project has been on for nine years now. So far approximately 23,000 primary school teachers have been trained across Nigeria through the cascade model of training.

**The ASEI-PDSI approach**

Eze (2012) asserted that for learning to be meaningful and effective in the classroom, the teacher should be able to select the appropriate teaching strategies that will be able to stimulate the interest of the learners and get them actively engaged in the process of learning. ASEI-PDSI approach is the effective approach for ensuring the quality of mathematics and science lessons and their steady improvement. The Activities, Students, Experiments and Improvisation (ASEI) are simply translated to 'lesson innovation'. This approach is an innovative approach that seeks to help teachers plan and use methods that focus on creating learning environments, opportunities, and strategies that enable learners to be in charge of their own learning. The ASEI lesson is however, made possible through PDSI practice (Plan, Do, See, Improve).The need for active learner involvement in the teaching and learning process as enshrined in ASEI should inform each and every aspect of the lesson that includes lesson planning, lesson implementation and lesson evaluation as well as incorporate feedback obtained in future lessons (CEMESTEA, 2018).

Figure 1 ASEI TENETS




## Methodology

### Research Design

A mixed method research design was used and both Qualitative and Quantitative techniques were employed to collect data from two states out of the 36 states of Nigeria and Abuja the Federal Capital Territory (FCT).

**Population:** The population of the study include: (i) all Science and Mathematics core teachers across Nigeria, (ii) SMASE Desk officers (iii) State Trainers, and (iv) Primary 4-6 pupils

### Sample Size and sampling technique

The sample size constitutes two states (Bauchi representing the North and Oyo representing the South), 5 schools in each state, two groups of teachers i.e. 19 SMASE trained and 16 Non SMASE trained teachers from same schools, as well as their pupils. SMASE trained served as quasi-experimental group and Non SMASE trained teachers as control group as against pre and post survey of similar subjects (SMASE teachers alone). They were selected from five schools in each state and the total number of pupils in class ranged from 7 to 83 across classes and school in the two states. Purposive sampling, stratified sampling, convenient sampling and single-stage simple random sampling techniques were employed as sampling technique (Cresswell, 2014).

Purposive sampling to select the two states, stratified sampling convenient sampling to select the schools and SMASE teachers; convenient sampling for the number of teachers and schools selected and single-stage simple random sampling techniques to select non-SMASE teachers.

**Research Instrumentation**

The SMASE and Non SMASE teachers and their pupils were assessed using evaluation tools designed to capture basic information for comparison across various factors as contained in the tools. The five evaluation tools used are: the class lesson observation checklist, ASEI-PDSI lesson observation checklist, pupils' participation questionnaire; teachers' record and Exit interview in order to determine the quality of teaching skills, degree of usage of ASEI-PDSI, degree of participation of students; teachers feeling towards teaching and factors facilitating/inhibiting implementation of ASEI/PDSI respectively (See table 1). Tools 1-4 were adapted from the SMASE Impact study 2008.

*Table 1: Evaluation Tools*

| | **Evaluation tools** | **Items evaluated** |
|---|---|---|
| 1 | Classroom lesson observation checklist | Quality of teaching skills |
| 2 | ASEI/PDSI lesson observation checklist | Degree of usage of ASEI-PDSI |
| 3 | Pupils participation questionnaire | Degree of participation of pupils |
| 4 | Teacher's record and Observation notes | Teachers' feeling towards teaching |
| 5 | Exit interviews | Factors facilitating/inhibiting implementation of ASEI/PDSI |

**Data Collection Procedure**

Each teacher was observed teaching a lesson of either mathematics or science, therefore nineteen different lessons of SMASE trained teachers and 16 lessons of Non SMASE trained teachers were observed. All the data were collected within three days in each state and within two consecutive months in the two state (May 2018 in Bauchi and June 2018 in Oyo). Researchers were assigned to collect information using the evaluation tools in the teaching process of the two sets of teachers and their pupils. In the implementation process the sampled teachers were briefed of the purpose of the survey by the researchers and were assured that the survey is neither relevant to teachers' promotion nor demotion, but rather to determine the relevance or otherwise of SMASE INSET. The researchers took a minimum of 35 minutes in a period to observe and fill out Classroom lesson observation checklist and ASEI-PDSI lesson observation checklist during mathematics or science lessons delivered by the sampled teachers. Subsequently, the sampled teachers were asked to assist the researchers in conducting Pupils' participation questionnaire after the lesson.

All data collection was conducted in the morning, between the hours of 9:30am and 1:00pm, covering primary 4 to 6. The total number of pupils in a class ranged from 7 to 83 with the presence of male students between 7 to 83 and female pupils between 8 and 57. The subjects covered were basic science and technology and Mathematics. Mathematics was taught twice more than the basic science and technology. In mathematics, the topics mostly taught were fractions, angles, addition of fractions and weights while in basic science and technology, the topics taught include Living things, Non-living things and Energy. Simple and brief exit interviews were also held with the teachers to illicit information about factors that facilitate or inhibit implementation of SMASE /ASEI/PDSI.

**Data Analysis**

Quantitative data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) to produce descriptive statistics. Mean scores and standard deviations, test of independent sample, t-test and frequency distribution where computed for each of the instrument and the two groups (SMASE and NON SMASE) teachers as shown in tables 2A – 2C. The qualitative data (observation notes on teachers' activity and pupils' responses plus the exit interviews) were written and transcribed and subsequently analyzed and interpreted using thematic analysis framework. Thematic analysis is effective in identifying, analyzing and reporting patterns or themes within data and interpreting various aspects of research topics. (Braun and Clarke, 2006)

**Findings**

***Table 2A: Mean Scores of Classroom Observation***

| Classroom Observation Checklist | | | |
|---|---|---|---|
| *Mean Score* | | | |
| | Mean of Category A | Mean of Category B | Mean of Category C |
| SMASE | 3.4408 | 3.2281 | 3.2237 |
| NON SMASE | 2.8828 | 2.4583 | 2.6719 |

Table 2A shows the mean scores of SMASE and NON SMASE teachers in relation to the three categories of the questionnaire; teaching procedure (Category A), fundamental techniques/methodology (Category B) and class management/control. The rating scale was based on poor, fair, good, very good and excellent, which was rated 1, 2, 3, 4, and 5 respectively. For all the three categories the SMASE trained teachers mean scores are above 3.0 indicating that they were rated well in respect to all the indicators. For example, in category A, the SMASE trained teachers were rated 'good' in terms of clarity/feasibility of lesson objectives, appropriateness of lesson, considering the content and language as well as emphasizing on main concept and achievement of set objectives. However, the rating of the Non SMASE trained teachers was overall fair in relation to all the parameters.

**Chart representing table 2A above Classroom Observation**

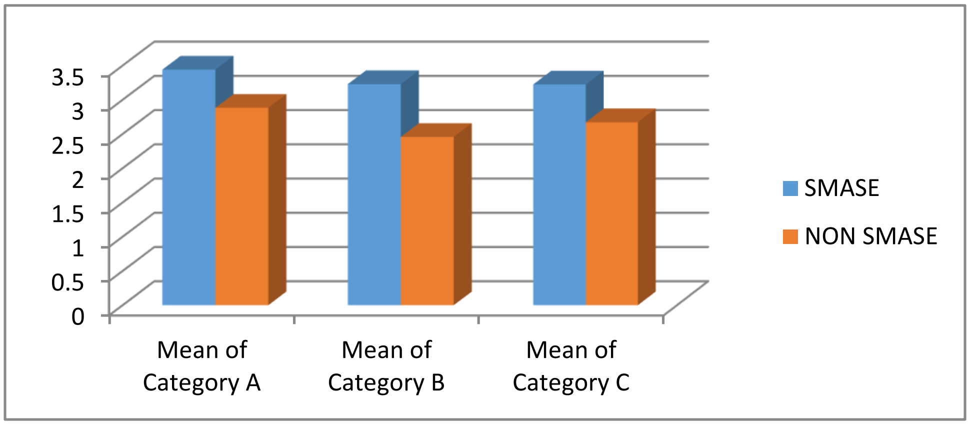



***Table 2B: Mean Scores of ASEI-PDSI***

| **ASEI-PDSI Checklist** | | |
|---|---|---|
| ***Mean Score*** | | |
| | **Mean of PDSI Category** | **Mean of ASEI Category** |
| SMASE | 3.2457 | 3.2361 |
| NON SMASE | 2.4258 | 1.9821 |

Table 2B presents the mean score of SMASE and Non SMASE teachers on ASEI (Activity, Student Involvement, Experiment effectiveness and Improvisation) and PDSI (Plan, Do, See and Improve). SMASE teachers are seen to be doing "good" in both ASEI and PDSI measures, on the other hand the Non SMASE teachers were doing "fair "or almost "poor" on those factors. For example, on ASEI, the Non SMASE teachers were almost not at all in line with the lesson planning processes and what it ought to achieve.

**Chart representing the table 2B *use of ASEI-PDSI***

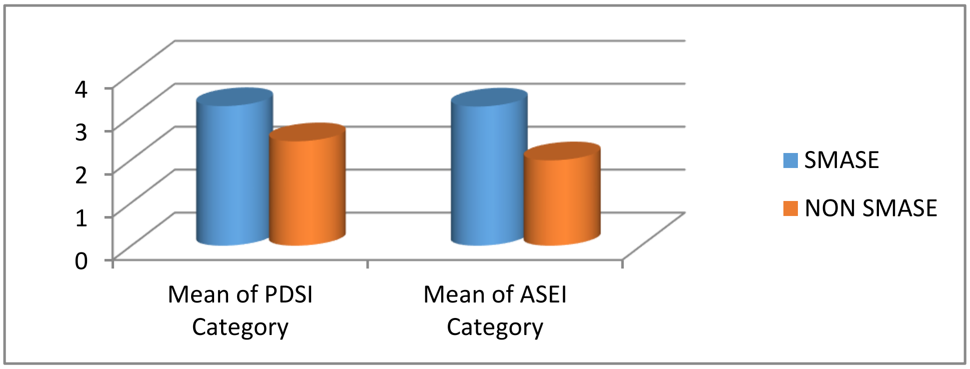
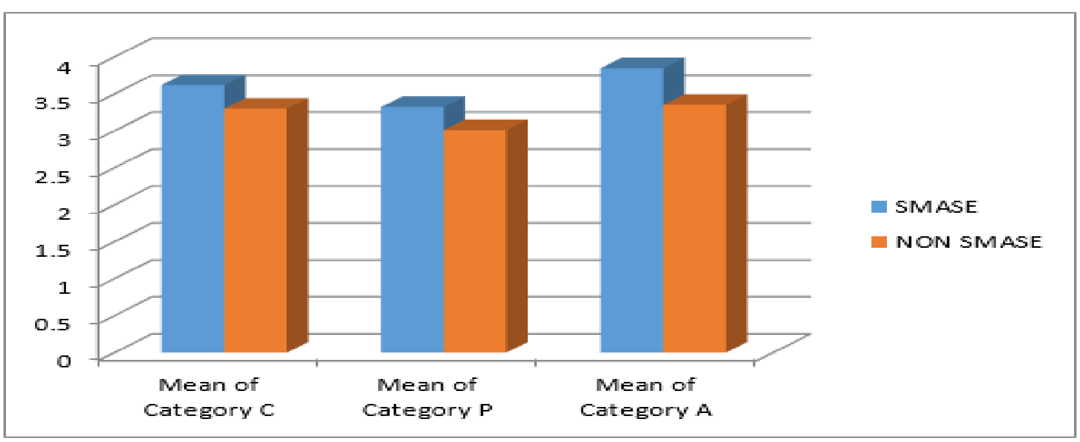



***Table 2C: Mean Scores of* Pupils' Participation**

| **Pupils' Participation Questionnaire** | | | |
|---|---|---|---|
| **Mean Score** | | | |
| | **Mean of Category C** | **Mean of Category P** | **Mean of Category A** |
| SMASE | 3.6190 | 3.3238 | 3.8466 |
| NON SMASE | 3.3000 | 3.0109 | 3.3515 |

In table 2C the mean scores of SMASE and Non SMASE teachers are shown in three different categories all related to pupils' participation in class. Overall, for both categories of teachers, the majority pupils seem to have participated at least once at one point in time in the course of their classes during the survey. Nonetheless, at all-time and categories, the SMASE teachers' pupils participated more as the mean score ranged between 3.32 and 3.85, while the Non SMASE teachers' pupils' participation mean scores ranged between 3.01 and 3.35.

**Chart representing table 3C Pupils' Participation**



**Discussion of findings**

**Extent to which teachers use ASEI/PSDI in teaching Mathematics and Science.**

The finding on the use of ASEI by teachers demonstrated good usage of ASEI/PDSI in teaching mathematics and science by SMASE trained teachers as seen in table 2B. It shows the positive impact of SMASE INSET on SMASE trained teachers as they were rated “good” in both PDSI and ASEI measures. Participants in the study including pupils reported that SMASE trained teachers prepare adequately for their lessons with well-prepared lesson plans, possess unique teaching skills and use variety of teaching techniques, they also improvise instructional aids.

On the other hand, the Non SMASE teachers were rated “fair “on same areas due to lack of exposure to SMASE INSET or other similar trainings as reported by non- SMASE trained teachers. For example, the Non SMASE teachers’ lesson plans were almost not in line with the lesson planning processes and what it ought to achieve. The teachers were heavily involved in talk and chalk/talk and talk /teacher-centered method of teaching as against the Activity-based, student-centered, experimentation and improvisation method. This finding is similar to that of Bolarin & Odofin (2014), and Udeson et al (2015) that teachers lack skills in lesson preparation, presentation and evaluation, improvisation of instructional materials, diversity of teaching methods and techniques, amongst others. Humphrey & Crawford, (2015) also reported that teaching and learning outcomes are below expectations

**a. Factors that facilitate and inhibit the processes of ASEI/PDSI use in teaching Mathematics and Science**

The finding in table 2A about classroom observation on teaching procedure (Category A), fundamental techniques/methodology (Category B) and class management/control (Category C) that for all the three categories the SMASE trained teachers mean scores are above 3.0 indicating that they were rated well in respect to all the indicators. For example, in category A, the SMASE trained teachers were rated ‘good’ in terms of clarity/feasibility of lesson objectives, appropriateness of lesson considering the content and language as well as emphasizing on main concept and achievement of set objectives. This result goes to show that there is awareness of ASEI approach in teachers that passed through SMASE INSET and they use ASEI in teaching mathematics and science to an extent especially when compared with their counterparts that were not trained in SMASE. They were found to employ skills like problem-solving approach, collaborative approach (think-pair-share), prediction; questioning approach etc. “*e.g. in mathematics teachers introduce the lesson by presenting learners with a mathematical problem to solve alone or in small groups and then call learners to present the solution they got to the mathematical problem”* (Observation field note- Oyo)

This result is similar to findings by Isoda & Katagiri, 2012 “*in Japan closely supervised, collaborative work among students is the norm..*.” they also posited that the Japanese teaching approach of problem solving is recognized as the teaching approach for developing higher-order thinking for human character formation.

The rating of the Non SMASE trained teachers was overall fair in relation to all the parameters hence, 97% non-SMASE trained teachers reported their unawareness about SMASE INSET, only 3% confirmed awareness of the SMASE approach. They also showed willingness to learn and use the SMASE techniques if they have opportunity to be trained. So it could be deduced that awareness about SMASE and participation in SMASE INSET facilitate the processes of ASEI usage, whereas unawareness and lack of capacity inhibits implementation of ASEI/PDSI in teaching and learning of Mathematics and Science. This goes to show that teachers are not re-trained and thus cannot give what they do not have, for them to be able to motivate learners' interest and participation that will improve performance in mathematics and science they need their capacity to be built first through re-training. Olumma & Nzegbulem (2015) opined that teachers require their skills, competences, and pedagogies be retooled or updated to be able to deliver in this ever-changing society. … teachers whose capacities are developed have imbued knowledge, skills, abilities, attitude and aptitude which promotes creativity, excellence, transfer of knowledge and skills to students. Inconducive environment, lack of encouragement and support were also cited as inhibiting factors by both group of teachers.

**b. Factors that facilitate and inhibit the processes of ASEI use in learning Mathematics and Science**

In table 2C the mean scores of SMASE and Non SMASE teachers are shown in three different categories all related to pupils' participation in class. Overall, for both categories of teachers, the majority pupils seem to have participated at least once at one point in time in the course of their classes during the survey. Nonetheless, at all-time and categories, the SMASE teachers' pupils participated more as the mean score ranged between 3.32 and 3.85, while the Non SMASE teachers' pupils' participation mean scores ranged between 3.01 and 3.35.

The finding indicates that teacher ability to engage learners is key to pupils' activeness or passiveness in class. This ability does not just happen, it is developed through capacity building and teacher professional development like SMASE INSET. "*The pupils' active participation in the lessons taught by SMASE teachers indicate that the SMASE training really enhance these teachers' capacities to develop mathematical thinking and scientific reasoning skills in pupils.*" "*…the pupils were given the opportunities to not only solve the task given by the teacher but also to consider, reason, reflect and predict as the case may be*" (Observation field notes, Bauchi)

"*a lot of group work and presentation by the students makes the class very lively and the students very active.*" (Exit Interview non-SMASE trained teacher- Oyo) Adedoyin (2010) as well as Danmole, Femi & Adoye (2004) further submitted that instructional approaches that involve the active participation of students could be more effective even in mathematics and science which requires the use of instructional strategies that enhance meaningful learning and acquisition of skills as many activities and concepts are involved.

**The most effective levels of intervention necessary for the implementation of ASEI/PDSI in teaching and learning of mathematics and science**

Excerpts from observation notes and reports of exit interviews revealed a need for more skills on how to plan lessons, prepare appropriate activities, skills on alternative experiments and improvisation of teaching/learning materials. There is need for teachers to re-examine their instructional approaches with the aim of refocusing classroom practices on ASEI/PDSI much more than obtained for effective teaching and for learners to reap maximum benefits from the teaching and learning process. This finding agrees with the findings of Watts & Allsop, (2015) that far too few teachers offer expertise in the core subject areas of mathematics, science and English. In addition, awareness of ASEI/PDSI approach from state level to schools is generally low, only the teachers that benefited from SMASE INSET seem to be aware of the training or the ASEI/PDSI approach. This is similar to the submission of Kontagora (2018) that the type of preparations (training and retraining) teachers receive play a key role in how effective they become.

## Conclusion

This study has successfully assessed the impact of SMASE INSET on Teacher Effectiveness and Pupils' Participation and Academic Performance in Mathematics and Science Education in Nigeria. Using a mixed -method research approach the study investigated the extent to which teachers that passed through SMASE INSET use ASEI/PSDI in teaching mathematics and science, the factors that facilitate and inhibit the processes of ASEI/PDSI use in teaching and learning mathematics and science and the most effective levels of intervention necessary for the implementation of ASEI/PDSI in teaching and learning of mathematics and science. based on areas of challenges identified.

From the findings it could be concluded that the quality of teaching skills (teacher effectiveness), degree of usage of ASEI-PDSI and the degree of pupils' participation in mathematics and science lessons of the trained SMASE teachers and their pupils was improved compared to the non-SMASE teachers and their pupils. This implies that through the SMASE INSET the trained teachers were equipped with ASEI skills which they employed to get learners to participate actively and perform better**.** Additionally, it brought out the skill gaps and areas of challenges for both groups of teachers and their pupils. The results also suggested the need to package a training to address areas of challenges and difficulty like higher order thinking skills, teaching of graphs, indices, place value, magnetism, basic electricity and electrical circuit, etc.

## Recommendations

In view of the findings and conclusions of this research and in order to achieve the maximum objectives of the programme, the following recommendations were made:

i. Curriculum developers should include the use of ASEI-PDSI approach in the teaching and learning of mathematics and science education in our schools so that more teachers both preservice and in-service can avail themselves of the ASEI/PDSI principle.

ii. The capacity of SMASE trained teachers should continue to be improved for effective delivery. The SMASE National Center should initiate an INSET package to address the gaps and challenges identified as areas needing intervention.
iii. There is need for concerted effort by all the SMASE stakeholders for full actualization and sustainability of SMASE INSET in our schools for quality education.
iv. One of the limitations of this study is the use of just two states out of 36 states and the FCT. The findings may not lend themselves to generalization to the states due to state peculiarities. There is need to scale up the impact study to the remaining states of Nigeria so as to determine the level of SMASE implementation and its effect as well as the challenges in the country.
v. There is need for proper funding of SMASE by the SUBEBs for effective cascade and implementation at all levels down to the school base, as it is the school base INSET is very weak and almost non-functional.

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Article 29

# Modeling simulations on individualized learning in Chemistry curriculum on students' achievement in Bungoma county, Kenya: Structure and bonding

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## Abstract

Successful Chemistry lessons depend on correct use of instructional pedagogy. During the 2018 and 2019 survey in Bungoma County on the difficulties in learning Chemistry, 70% of the learners said they would understand structure and bonding better if they are involved in practical work. This study investigated modeling simulations achievement on the mean performance by individual learners. The quasi-experimental design used pretest-posttest control group with 2x2x2 factorial matrix among 120 form two Chemistry students from 3 County schools; pure boys, pure girls and co-educational gender of 2 sub-groups (20 each per school), and the ratio of boys to girls in the co-educational school was 1:1. The experimental groups constructed models while control groups used lecture method. Structure and bonding examination test (SBET) on Bloom's taxonomy was the research instrument. The data collected was subjected to analysis of variance (ANOVA) by SPSS software version 16.3, and mean comparison done by the Least Significance Difference (LSD) at $P < 0.05$ confidence level. The experimental group obtained a mean of 84.6 % higher than the control group with 49.2%. Chemistry teachers to incorporate learner's model construction for effective teaching-learning process, of high cognitive skills that require application of psychomotor skills.

**Key words:** *Chemistry, Modeling Simulation, Structure, Bonding, STEM Curriculum.*

## Introduction

Modeling is a flexible procedure oriented to manipulate abstract and complex chemistry structures, symbols and graphics in order to classify information. Active involvement of learners through practical construction of models in a multi-disciplinary classroom, improves concept internalization, learner growth, attentiveness and enables the teacher to effectively deliver a quality lesson, because the learners are involved in drawing conclusions. The modeling simulation approach uses stepwise methods to explore the approximate behavior and orientation of a designed structure. Improvised use of carbon models, chewed ball gums, round 'bandas', bottle straws and plasticine to construct chemical structures in the classroom set-up, have gained a wider application in the field of structure and bonding, organic chemistry, particle physics, and 3-D structures in molecular biology and medicine in the field of research. The United States Defense Modeling and Simulation Coordination Office (USDMSO) identifies three main types of simulation: live, virtual and constructive. Live simulation encompasses live action, virtual simulation is primarily used for training purposes while constructive simulation is used to view or predict outcomes like war gaming or stock market behaviour (Umoke & Nwafor, 2014). This study embraced a high percentage of constructive simulation to establish the level of content mastery in the topic of structure and bonding.

Chemistry is an integral part of science focusing on demystifying abstract concepts through constructive simulations of innovative lesson activities by constructing NaCl, $NH_3$, $NH_4^+$, $PH_4^+$, $H_3O^+$, $SO_2$, $SO_3$, CO, $Al_2Cl_6$ among others that are commonly used as basic examples in form two structure and bonding Chemistry syllabus. An analysis of the Kenya National Examinations Council Chemistry report (KNEC 2017) revealed that learners were inadequately exposed to practical work in structure and bonding topic, which attempts to revise the sub-topic of chemical formulae through writing the correct chemical symbols and formulae by constructing structural models. The case gets worse for average and below average learners who could not distinguish between various chemicals used in some experiments and understanding the concept of metallic bonding in Na, Mg and Al metals. Some learners were unable to visualize and identify the $NH_4^+$ formed when $NH_3$ gas is combined with the $H^+$ owing to the instructional pedagogy employed. In Kenya for instance, schools play an important role in educating the society (Knippels, 2002) on the impact of new research on chemical manufacturing, medicine and lifestyles with the view of helping the people understand the issues involved. Many students and teachers consider chemistry a difficult subject to learn and understand (Knippels *et al*., 2005; Chu, 2008) due to its abstractness, misconceptions, misunderstandings and complexity of the processes involved that are not physically observable. The study on chemistry education by Wachanga and Mwangi (2004), identified major difficulties in the domain-specific abstract nature of the subject and the complex nature of sequential processes. Students struggle to visualize, conceptualize and comprehend the chemical formulae and structures while the chemistry educators also struggle to lecture, assign tasks from textbooks, which require additional teaching aid models to simulate the learners understand. Simulation models are used for prediction, understanding and exploratory purposes in widening the learners' scope of understanding in the topic of structure and bonding. From research, visual perception helps students understand complex processes, by converting the abstract concept into a specific visual object that can be mentally manipulated. Research by Kraidy (2002) has also shown that, by using well-designed visual models, students can digest large amounts of information in a relatively short time and construct their own personal visualization stage-wise-process.

The use of models to communicate ideas, fosters long-term memory by calling attention to objects during the early steps of instruction, and reduces the abstractness associated with the temporal transitions of the process (Rieber, 1994). The value of structural graphics appears to be associated with the dual-coding theory (Paivio, 1991), which suggests that long-term memory retention is facilitated by a combination of verbal words and external visual pictures, which activates the coding system in an additive way (Paivio, 1986), and when information is dual-coded, it increases the retrieval probability because the words and pictures activate mental processing in different ways (Aremu & Sangodoyin, 2010). Chemical models have been used in science teaching to help students understand complicated science topics, because they stimulate more than one sense at a time, and therefore make them more attention-getting and attention-holding (Akpinar & Ergin, 2008). This study investigated the incorporation of modeling simulation technologies as compared to conventional lecture method in the teaching of structure and bonding in secondary chemistry curriculum. There is fairly extensive literature arguing that modeling structures are effective in using static sequential images for teaching dynamic events (Tversky & Morrison, 2002). Modeling simulation images provide a wide range of stimuli that increases students' engagement in learning during the teaching-learning process in a teacher facilitated approach, where both teachers and students may control the pace of lessons according to their ability to manipulate the modeled structures (Aremu & Sangodoyin, 2010). This phenomenon imparts in learners the problem solving approach, enhances recall of the visual structured aids by learners who quickly connect with the current situation and effectively address radical changes in structure and bonding and science research (Smetana & Bell, 2012).

**Problem statement**

Successful innovation and scientific literacy depends on equipping future generations with a solid knowledge base in chemistry and related STEM subjects, combined with the thinking tools, models and strategies to understand complex concepts and provide solutions. Kraidy (2002) reports that there is a lack of adequate higher order thinking ability among chemistry students when handling Blooms' taxonomy questions in the topic of structure and bonding, hence the need to prepare learners for effective problem solving, thoughtful decision making and life-long learning processes. Imparting particular important skills in STEM-related fields that often require deep engagement with complex content which requires a high degree of critical-thinking and problem-solving abilities. Effective and efficient teaching of Chemistry generates the greatest opportunity for students to learn and technically manage instructional pedagogy. Modeling simulations learning methodology enables students to help one another to learn in small manageable groups through structure construction of models. Pressure to construct and conform benefits all students by cultivating trust amongst each other, communicate effectively, accept and support one another, and resolve conflicts constructively.

Despite the noticeable gains in chemistry exams observed over the years, the Education blueprint notes that the gap between topical performance in chemistry is widening with structure and bonding being inclusive. There are several factors underlying the declining performance and quality of student grades in chemistry due to a general lack of awareness among students and teachers of the dynamic hands on approach of learning the subject and individual topics. The report by KNEC (2017) volume 2 further recommended comprehensive teaching of structure and bonding with clear emphasis on illustrations of all the processes involved in the model construction involved in the teaching and learning process. However, the question that this study partially answers is, do teachers implement the KNEC reports fully? This study established that 51% majority teachers do not implement KNEC reports and rarely or missed improvisation of teaching-learning materials (CEMASTEA, 2015). There is not enough current studies investigating the effectiveness of modeling simulation in teaching and learning structure and bonding in Kenya.

**Null hypothesis**

The following null hypotheses were tested at 0.05 alpha (α)-level.

$H_0$1: There is no statistical significant difference in the understanding and retention of the chemistry concept of structure and bonding taught using the traditional lecture method and modeling simulations instructional pedagogy.

$H_0$2: There is no statistical significant difference in the mean achievement of scores in the structure and bonding examination test by chemistry students taught using conventional lecture method and those taught using modeling simulations approach.

$H_0$3: There is no statistical significant difference in the mean performance of questions tested on structure and bonding between gender of boys and girls in the teaching of chemistry using modeling simulations method.

**Methodology**

This paper presents a systematic modeling simulations approach to teaching structure and bonding in the KCSE science education curriculum of form two chemistry syllabus using modeling simulation structures made from chewed ball gums, round 'bandas', bottle straws and plasticine of different colours to represent electrons and energy levels. This study employed the quasi-experimental research design, involving the pretest-posttest control group design with a 2x2x2 factorial matrix (White & Sabarwal, 2014). The researchers used two natural intact groups of students whose ability was based on school records, one experimental (modeling) and the other control (no treatment) with intact classes. Demonstration was done in three schools from Bungoma County (1 pure boys, 1 pure girls and 1 mixed boys and girls), with a total of six certified professional chemistry teachers (2 from each school) and one twenty form two chemistry students (40 from each school). The schools had comparative age of students, with similar background in chemistry and experienced in constructing models of chemical structures. All schools had at least one chemistry laboratory with 10-20 functional model boxes with learning materials, to represent the ability levels of learners. The sampled students were assigned purposively and randomly by the teacher administrator selection, numbers from 1 to 40 in each school, and divided into two intact groups of twenty using even and odd numbers. The even numbers comprised the modeling experimental group while the odd numbers comprised the control group to minimize the spurious impression and efficacy of examination scores. The mixed school had 20 girls and 20 boys subjected to the same sampling treatment, with 10 boys and 10 girls in each experimental group. The teachers-sex and teachers-sex-method interactions were not considered because they make no sense conceptually (Campbell & Stanley., 1963). Although upon beginning of instruction in structure and bonding, the teacher used numerous examples of each sex, but not just one of each as a precaution to standardize exact replication within the study while distributing the materials for model construction. All the control groups were given a pretest only while the modeling groups were given both a pretest and post-test. The students were taught metallic, ionic, covalent and coordinate/dative types of bonds with their corresponding giant metallic, giant ionic, giant atomic and simple molecular structures using practical modeling simulations practical approach for the experimental groups and conventional teacher centered lecture method of chalk and talk for control group (Thomas & Israel., 2014).

| **Experimental groups** | **Control** | **Modeling simulations** |
|---|---|---|
| Pure boy school | Pretest | Pre-test, post-test, Post-posttest |
| Pure girl school | Pretest | Pre-test, Post-test, post-posttest |
| Mixed boys and girls school | Pretest | Pre-test, Post-test, Post-posttest |

Table 1: Experimental design

## Research instruments

### Structure and Bonding Examination Test (SBET)

Chemistry researchers from the School of Natural Sciences (SONAS), Biological Sciences department of Masinde Muliro University of Science and Technology, prepared 20 objective structure and bonding examination test (SBET) questions, based on the models intended for construction (Figure 1) and Bloom's taxonomy of education objectives, to test the learners' analysis, application, comprehension, evaluation, knowledge, retention and synthesis. The 20 well designed and structured achievement test on structure and bonding were reviewed by experts in chemistry and science education from SONAS. The SBET questions were assigned a total of 40 marks to cater for equal mean score for all the questions that were piloted on 120 students who are not participating in the study, as a trial test and applied the Kuder-Richardson 21 reliability coefficient of 0.82 (Popham, 1990), which was above the 0.70 threshold for acceptable reliability (Fraenkel & Warren, 1990), to assess internal consistency and reliability of dichotomously scored questions that are all about the same difficulty on knowledge, comprehension and application.

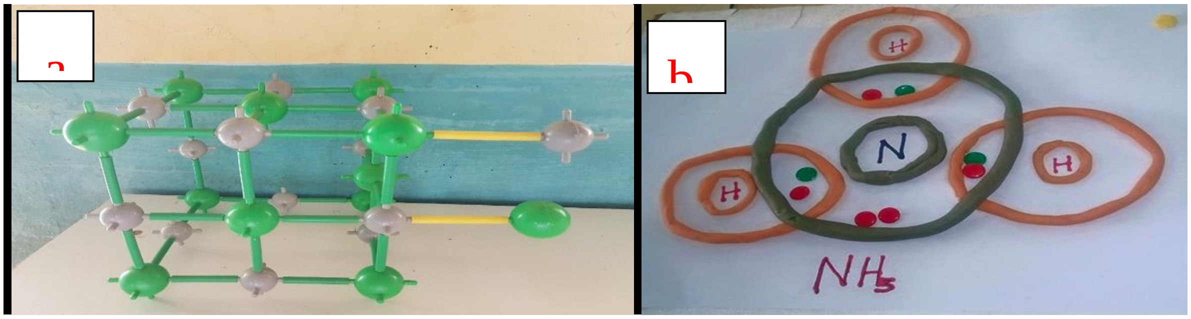

Fig. 1: Some model simulation structures; **a**: NaCl lattice. **b**: $NH_3$ structure

**Results**

**Pre-test Results**

This test allowed the researchers to test the significance of hypothesis one, $H_01$ ($H_01$: There is no statistical significant difference in the understanding and retention of the chemistry concept of structure and bonding taught using the traditional lecture method and modeling simulations instructional pedagogy) and exert complete control over the variable results from the 120 students who sat the test questions after being taught by traditional lecture method. The degrees of freedom (df) and t-values were calculated from the data obtained and fitted into SPSS software version 16.0 to obtain the P-value at $p \leq 0.05$ confidence level.

| **Group** | **Mean** | **SD** | **df** | **t-value** | **P-value** |
|---|---|---|---|---|---|
| Boys | 11.60 | 5.225 | 119.0 | 0.023 | 0.01 |
| Girls | 11.95 | 5.356 | 119.0 | 0.023 | 0.01 |
| Mixed Boys & Girls | 11.95 | 5.236 | 119.0 | 0.023 | 0.01 |

Table 2: Summary of Pre-test results.

The statistical results are not significantly different because the t-value = 0.023 and df = 119.00 has a P value of less than 1 at $P \geq 0.05$ confidence level. This results indicate that the obtained difference between the arithmetic means of the three groups is not significant hence the study groups were suitable for this research because they had similar features, characteristics and performance means that were not significantly different (Thiong'o, 2014).

**Post-test results**

In order to establish the effect of modeling simulations on the topic of structure and bonding in chemistry, the analysis of post-test arithmetic mean scores were calculated to test the Ho2 ($H_02$: There is no statistical significant difference in the mean achievement of scores in the structure and bonding examination test by chemistry students taught using conventional lecture method and those taught using modeling simulations approach). This results also tested Ho3 ($H_0$3: There is no statistical significant difference in the mean performance of questions tested on structure and bonding between gender of boys and girls in the teaching of chemistry using modeling simulations method). These findings established the authenticity and validity to reject or fail to reject the Ho2 and Ho3, if there was a statistical significant difference in the achieved scores between the modeling simulations group and the control group.

| Group | Number of students (N) | Mean | S.D |
|---|---|---|---|
| Boys' Simulation group | 40 | 17.05 | 3.49 |
| Girls' Simulation group | 40 | 17.80 | 3.58 |
| Mixed boys' and girls' Simulation group | 40 | 18.20 | 2.98 |

Table 3: Summary of Post-test results.

The post-test results indicate that modeling simulations has a positive correlation with mean performance as compared to other traditional conventional lecture methods. The post-test results were subjected to one-way analysis of variance (ANOVA) that was performed to determine whether the mean scores had a statistical significant difference (table 4). The sum of squares (SS) showed the measure of dispersion among the mean scores with inconsistent homogeneity (less homogenous), and the larger the dispersion of consistent means among the scores (more homogenous) with smaller dispersion.

| Group | SS | df | MS | F-statistic | P-value |
|---|---|---|---|---|---|
| Between groups | 1380.2276 | 2 | 460.0759 | 22.5016 | 0.009 |
| Within groups | 2433.1213 | 119 | 20.4464 | | |
| Total | 3813.3489 | 122 | | | |

Table 4: The ANOVA table of the Post-test scores.

The mean percentage results of control groups (49.20%) and modeling simulations (84.60%) were statistically significant at F-critical value = 22.5016 and P-value of 0.009 at $P < 0.05$ confidence level. This also indicates that the MS within > MS between. This results indicate a high significant overall achievement using modeling simulations effect on students' performance than using the regular lecture method.

## Discussion

An analysis of the SBET results showed that learners encountered challenges and performed poorly with items that required application of knowledge involved in showing how bonding processes occurred through drawing dot (.) and cross (x) structures but instead performed better in those that needed factual knowledge. Planning and organization of the steps followed in model construction of the specific structures and bonds in a logical sequence revealed skill weaknesses that once incorporated, could make accurate observations, recording and making acceptable scientific explanations and logical inferences. The chemistry students who were taught structure and bonding using modeling simulations method, had higher achievement (posttest) scores of 84.60%, indicating that they understood the concept more than those taught using conventional lecture method who scored 49.20%. The overall standard deviation indicated that the SBET examination significantly discriminated candidates of different abilities. There was a significant difference in the understanding and retention ability of the two control and modeling simulation groups as evidenced from there mean score achievement and the t-value of reliability. This is in conformity with research by Chu (2008) whose findings suggested that model pictures leads to long term memory and therefore, students exposed to simulation modeling instructional strategy retained more knowledge than those taught using conventional lecture method. These findings are also supported by Lin, (2011) who in his study revealed that animations lead to greater long-term memory retention of learned materials. The modeling simulation group recorded higher mean score achievement than those taught using lecture method, showing that there is a higher significant difference in the academic achievement of the two groups.

The topic-based analysis in chemistry reveals difficulties learners experience in bringing to fore what they have learnt during the scheduled time, and it points to inherent issues in the teaching-learning process. The root cause could stem from inadequate involvement of learners in problem solving situations and teaching mainly through telling as opposed to individualized practical experiences. It also points to the extent of understanding of concepts by learners which is mainly in the lower order of skills including knowledge and comprehension. Comparison of the means achieved by boys and girls in the SBET of the modeling simulations group, showed that there was no significant difference in the performance of both gender of students in the concept of structure and bonding at $p \geq 0.05$ confidence level. This was as a result of the modeling simulation effect which improved the performance of both gender of chemistry students. These research findings agree with the study by Aremu and Sangodoyin, (2010) who found no significant main effect for gender with regard to Biology students' academic mean score achievement in STEM subjects.

## Conclusion

In conclusion, modeling exposes learners to frequent handling of objects and apparatus in lessons hence enhancing their manipulative, observation and recording skills which forms a basis of innovativeness in learners. The results of this study strongly indicate that modeling simulations of structure and bonding improved performance mean scores, understanding and retention ability showing that students had taken charge of their learning and the teachers had started embracing learners' ideas.

**Recommendations**

This study therefore recommends that chemistry teachers should incorporate practical approach and use real life examples of items made from bonds when teaching structure and bonding topic. The students should be allowed to carry out hands-on practical work of model construction used during the teaching-learning process. This will ensure that the content is effectively delivered and provide an enabling environment for learners to adequately answer questions of high cognitive demand that requires application of psychomotor skills.

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**Article 30**

# A review of the lessons learnt from learners through the implementation of the Experimento program in low income public primary schools in Nairobi County-Kenya

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**Abstract**

In July 2019, Impacting Youth Trust, Siemens Stiftung and the Teachers Service Commission conducted field assessments of 30 public primary schools out of over 90 Experimento Program beneficiary schools in Nairobi County. The purpose of the assessment was to gather data on the impact of the practical, discovery and leaner centered approach to STEM education that supports the implementation of the country's 8-4-4 and competency-based curriculum. During the assessment, the team was able to identify lessons from the learners on the areas of attitude change, creativity, improvisation, inclusivity and importance of creating platforms for children to showcase their innovations. Introduction of the Experimento program in schools has had a direct correlation to the improvement of the learners grades to match the 21$^{st}$ century skills through teachers switching their instruction methodology to a more practical approach. Learners with supporting resources including locally available materials can actively conduct experiments that are covered within the curriculum at home thus involving their parents in the learning process. Inclusivity is one of principals that guides the experimento program by encouraging all children to participate actively in STEM learning has resulted to average learners to embracing STEM in a manner that they best understand.

**Key words:** *Practical based approach, 21$^{st}$ century skills, Competency based curriculum*

**Abbreviations:** *STEM – Science, Technology, Engineering and Mathematics; 8-4-4 curriculum – 8 years of primary school, 4 years of high school and 4 years of university education curriculum; Three Rs – Reading, Writing and Relevance; 3Cs – Creativity, Communication and Collaboration.*

## Introduction

### Background

21$^{st}$ century skills have been pegged as a necessary foundation in the provision of skilled employment to future economies of the world. Most education systems continentally have been driven by systems that were set up based on the education systems that existed pre-independence Africa. These learning systems have often taken little consideration to issues such as context and indigenous knowledge thus leading to noticeable gaps in the education pathways.

Twenty-first-century learning means that students master content while producing, synthesizing, and evaluating information from a wide variety of subjects and an understanding of and respect for diverse cultured. Students demonstrate the three Rs, but also the 3Cs: Creativity, communication and collaboration. [1]. The 21$^{st}$ century skills which include critical thinking, creativity, communication and collaboration encourage learners to ask why and take charge in their learning process through the facilitation of their instructors.

STEM based careers have been greatly affected by subject uptake into higher education levels which has affected the supply of STEM professionals to the economy. In Kenya, performance of STEM subjects in the high school exit exams has been a good indicator of how much effort and deliberate interventions are needed to ensure that the education system at all levels promotes quality learner experiences. Promotion of STEM education is a much needed initiative to encourage well-rounded education essential for Kenyan students and address the imbalance in or education systems [2]

Twenty first century skills have led to significant changes in teaching and learning techniques in STEM. Learners are able to discover truths through direct interaction with STEM where they can differentiate between facts and misconceptions using different concepts and interdisciplinary connections. Learners utilize their abilities to look at a problem from multiple perspectives and present them in a concise manner which often encompasses peer sharing and collaboration. Learners who utilize the 4Cs in STEM are able not only to grasp the competencies but also develop their social and emotional intelligence.

Learner engagement is a measure that reflects the quantity and quality of learners' participation in their courses and every aspect of their education program. [3] An engaged learner should be eager to participate in the classroom, be an active participant in their learning process, be motivated to go beyond their class work and inspired to be learn more.

**The case study- Experimento program**

Student centered approaches are concerned with the students' needs, abilities, interests, and learning styles, with the teacher as a facilitator of learning, helping students access and process information. [4] Quality education is a global prerequisite for individual development and participation in society. In a technology-driven world, understanding scientific and technological interrelationships is paramount for responsible societal involvement. Vision 2030, African Union Charter and the Sustainable Development Goals have laid emphasis on S.T.E.M as a development tool that encourages innovation, industrialization and manufacturing in Kenya. The Experimento program which is being implemented in Latin America, Africa (South Africa, Kenya, Nigeria and Ghana) and Germany provides educators with practical training, continuing education opportunities and high-quality teaching and learning materials. The educational materials are readily available in digital form to provide equal support for all pupils. [5] The program's engagement bundles discovery-based learning in three thematic areas: energy, environment and health with value-building actions that help to shape a socially oriented strong character. The training and materials help educators craft a modern science and technology education based on experimental classroom lessons that ensures that children are at the centre of the learning process while gaining the most out of the learning experience. Additionally, the two teachers trained per school are expected to go back to their schools and conduct peer teaching with the rest of the teachers where they step in as multipliers of the program. The trainers that are facilitate the training are teachers who have mastered the Experimento program approach.

In the past, emphasis has been on high school and institutions of higher learning as strategic entry points for innovation and creativity. The Experimento program which is being implemented at the primary school level in Kenya is working in collaboration with key stakeholders to build a foundation for learners at the primary level as an entry point to understand and apply S.T.E.M knowledge. The Experimento program though its teacher training, provision of the science kits and instructional materials, access to the media portal, access to an alumni teachers network, provision of showcasing platforms for the Experimento program teachers and learners and provision of innovative grants for innovations has aligned itself with the Teachers Service Commission and Ministry of Education mandates. The program supports the Teachers Service Commission Standard 2- Competency based curriculum and pedagogical content knowledge in support of improving the content and content delivery skills of the trained teachers in the instruction of STEM topics.

In Kenya, the Experimento program has trained teachers from over 90 schools in Nairobi country and reached over 100,000 learners since its introduction in Kenya in 2014. Teachers who have gone through the program are recognized as STEM champions by the Teachers Service Commission because of their understanding of learner engagement and importance of child centered learning in STEM. The schools are selected using non-discriminatory criteria that takes into consideration: the location of the schools within the 16 zones in Nairobi County, the performance of the school where poorly performing schools are given priority, the population of the schools where schools with higher number of learners ae prioritized and a quota system for special needs learners.

**Research Methods**

Siemens Stiftung, Impacting Youth Trust and Teachers Service Commission conducted an impact assessment analysis activity in July 2019 through the distribution of logbooks and field visits to 30 schools from the more than 90 schools who have benefitted from the Experimento program. [Appendix 1 and 2]. This activity was one of the recommendations made during the monitoring and evaluation activity conducted in 2018. Data has also been generated from teachers and school updates shared with the Experimento team, collected pre and post training surveys during teacher trainings and questionnaires that have been on file from 2014.

**Study population**

The study population was 30 schools from the 16 zones in Nairobi county where the field visit team observed an Experimento based class. The lessons were facilitated by first generation trained Experimento teachers and other teachers who have benefitted from school level peer teaching.

**Data collection**

The data collection methods used collected qualitative and quantitative data. The data collections tools that were used included surveys, questionnaires, focus group discussions with learners and teachers, learner experience observations, program school progress logbooks and teacher observations.

**Data analysis method**

The statistical method used to analyze the data was the cluster and factor method.

**Results**

The observations below are an average of results of the 30 schools visited in July 2019.

1. The average education level of the teachers was a degree in education followed by a diploma in education with 16 schools having instructors with at least a degree qualification.
2. The average years of educators in the teaching profession was 6-10 years.
3. The average number of teachers who have been practicing the Experimento approach in the schools is two years.
4. The average number of learners in a class was 57 where Ndurarua primary had the largest number of learners in a class with 127 learners in the observed class and City primary had the least number of learners with 27 learners not including the special needs unit.
5. 4 out of the 30 schools visited had a special needs unit and 2 handicapped special needs unit were utilizing the Experimento program approach.
6. The average school performance improvement was 5 points in the Kenya Certificate of Primary Education examinations with Lang'ata West primary school being the most improved.
7. 6 out of 30 schools conducted science congress activities to showcase innovations where learners were able to show the application of the curriculum and Experimento approach in a practical manner.

*Using the legend below, the results of the observations made were as follows:

**1**-Not observed **2-**Below Basic **3**-Basic **4**-Proficient **5-** Highly Proficient

**Part A**

| | Performance Indicator | Result |
|---|---|---|
| 1 | How well is the teacher prepared in class? | 5 |
| 2 | How well is the teacher connecting with learners' prior knowledge? | 4 |
| 3 | Is the teacher using appropriate approaches and the Experimento pedagogy? (hands-on and inquiry-based learning) | 5 |
| 4 | Is the teacher encouraging and sustaining learners' interest in the subject? | 5 |
| 5 | Is the teacher providing scenarios that encourage learners to use critical thinking skills? | 4 |
| 6 | Are the learners asking questions during the lesson? | 3 |
| 7 | Are the learners' grasping STEM concepts during the lesson? | 4 |
| 8 | How efficient is the teacher in utilizing class time? | 4 |
| 9 | How skilled is the teacher inn holding class attention? | 4 |
| 10 | Is the teacher using the EXPERIMENTO kit to support instruction in the classroom? | 4 |

**Part B**
**Overall rating**

| | | |
|---|---|---|
| 1 | Rate the teacher's ability in using management techniques in the classroom | 4 |
| 2 | Rate learners' ability to capture STEM content | 4 |
| 3 | Rate teacher peer teaching activity | 4 |
| 4 | Has the performance of the school improved | 4 |

*Figure 1: Results of the survey conducted in 30 Experimento schools in Nairobi County.*

The overall findings indicated that the Experimento program and more specifically the practical based approach in STEM in the beneficiary schools has been impactful in the delivery of STEM concepts to learners. The results also highlighted the need for deliberate training of teachers on how to positively engage learners in asking questions during STEM lessons. This is already being addressed by the training team in partnership with the Teachers Service Commission to ensure that teachers who participate in the Experimento program are trained on how to actively encourage learners to ask questions during lessons.

**Discussion**

From the data collection activities conducted by Impacting Youth Trust, Siemens Stiftung and the Teachers Service Commission, the following learner centered lessons were observed.

1. Assessment methods

   The team noted that the current standardized assessment method in use have discouraged learners from having a positive attitude towards STEM and dispirited them from easily pursuing STEM based subjects in later years. The learners are often discouraged from having a keen interest in STEM because of their poor performance in the assessments. It was noted that there is a need for alternative methods of assessing learner interests and increased in depth understanding that takes into consideration the learners' interests, language, family background and accessibility to information.

   The team noted that children who were beneficiaries of the Experimento approach and were under the competency-based curriculum were more innovative and confident in exploring their creative and critical thinking skills than those in the 8-4-4 education system.

2. Identification of gifted learners

   The field visits which included out of class activities such as science congresses noted that there are advanced learners who stand out as highly gifted children but fail to be identified within the system because of their poor academic performances. Out of the 30 schools visited, 6 learners stood out as gifted children because of their ability to grasp STEM concepts that were beyond their age and curriculum scope. Teachers provided feedback that most of these children are poor academic achievers because of their advanced understanding of the concepts, lack of understanding by the education fraternity and lack of further support from their teachers and guardians.

3. Instructional materials

   Learners with the support of the Experimento program kit interacted with STEM first-hand and further improved and generated new experiments from the kit provided. The team noted that learners if provided with the necessary materials at any level of primary school education can explore their critical thinking, creativity, communication and collaboration skills to embrace STEM concepts and further solve community problems.

4. Learner participation

   The team noted that with discovery-based pedagogy, the learners' attitudes towards STEM changed and teachers' openness in allowing the children to question experiential outcomes during class work increased learners' participation in class. Their interest to attend STEM classes increased because the experience was fun and relatable to their day to day life.

5. Importance of grouping strategies

   Cluster grouping during STEM lessons was noted as a forward-thinking strategy in dealing with a classroom setting with a high number of learners and limited materials to conduct experiments. Children can learn alongside each other regardless of their academic abilities and practice peer teaching. Learners can move around and interact with each other freely during class activities thus gaining life skills during their interaction.

6. Social and emotional intelligence development of learners

   STEM in a social setting where learners interact amongst themselves while discovering and exploring concepts develops additional skills that prepare them for interaction with the outside world. Tolerance, nationalism, cohesion, teamwork, sharing and collective responsibilities are some of the skills the team observed in the children during sessions where children were conducting experiments.

7. Introduction of specialized classrooms

   The team noted that some of the learners who had a strong understanding of STEM concepts were very weak in courses that did not have a practical approach in their instructions. As a result, such learners had a uniquely skewed learning curve where their general interest was in STEM areas and not in the other areas such as languages. The team noted the importance of a specialized curriculum and classrooms that take into consideration the learners' interests and strengths by allocating more time to these areas of interests. These changes will acknowledge and address specific learners needs through a curriculum that invests more time and resources in STEM areas whilst providing basic know how in areas that they struggle in to ensure the provision of a holistic experience for these children.

8. Improvisation

   The Experimento program provides teacher training, kits and support so that learners can use the knowledge provided in the curriculum to become change makers. The team observed that learners when provided with challenges to solve problems, they were able to improvise and generate their own solutions by using cheap and locally available to create innovations. Additionally, the learners were able to utilize concepts that took into consideration humanitarian effects to their communities.

9. Importance of creation of STEM innovation platforms

   Schools that conducted science congress activities in their schools showcased experiments that should be advanced to national and international platforms because of their ability to use locally available materials to generate new ways of developing innovations. Teachers with the right training have a better chance of creating more platforms within the schools to encourage innovation in STEM at primary school with the right support.

   The team noted that learners who had been provided with $50 grants from the Experimento program to further develop their innovations had improved on their experiments and further developed more innovations. This proved that with further investments in learners who are strong in STEM through small grants can greatly contribute towards a robust system that creates innovators and entrepreneurs from primary schools and nurture them to be future entrepreneurs.

10. Inclusion

    The team observed that the schools that had special needs units geared towards deaf and dumb children were using the Experimento approach to support the learners' education experience through practical work. Learners with physical handicaps with the support of practical STEM experiments had a better grasp on the concepts taught to them.

**Figure 2:** *Experimento teachers receiving kits*


***Figure 3****: Experimento children showcasing experiments*

## Summary

The findings from the assessment activity conducted in 30 schools benefitting from the Experimento program in Nairobi County highlighted that education stakeholders should make more investments in the adoption and adaptation of practical based approaches in STEM education. This will ensure that learners engage STEM topics with the aim of preparing them for the future needs of the African continent in relation to the global trends. An approach such as what is offered by the Experimento program can be utilized in setting up structures and instructional approaches that ensure a learner is at the centre of the learning process in STEM education. Investments in continuous professional development of teachers, research on STEM education for the African context, utilization of locally available materials in STEM instruction and creation of innovative platforms at lower levels of basic education should be prioritized continentally. These interventions will result to an increased impact of STEM education for the benefit of the African continent through skills development and fostering community based solutions that will lead to poverty reduction, decent living and overall development.

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**Article 31**

# Colla-Petitive strategy for collaborative learning environment in schools

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**Abstract**

Developments in Science, Technology, Engineering, and Mathematics (STEM) subjects can accelerate the achievement of industrial and technological advancements in any nation. Developing countries can adopt workable formula from developed countries like Finland, Germany, Singapore, and Japan, which have already implemented competency-based curricula with emphasis on STEM and collaborative learning. With the introduction of the Competency Based Curriculum (CBC), more emphasis is being laid on the development of competencies and collaborative learning. Observably, learners prefer activities that pool them into teams for collaborative competition among different groups and prefer science and mathematics subjects due to the pedagogy employed by the teacher. With this marked influence, teachers hold a component element in the establishment of a collaborative learning environment, instilling confidence, and promoting interpersonal skills in all learners. The firm developed a colla-petitive pedagogy to promote collaborative learning, critical thinking, problem solving, and self-efficacy. Schools that employ colla-petitive pedagogy have realized improved academic and disciplinary performance. For instance, Nyakiambi Primary school in Nyandarua County realized a positive deviation of 23.46 point average in 2017 KCPE and 22.77 point average in the 2018 KCPE results. Others include Vanessa Grant Girls' High School, Kambala Primary School, and Kinare Primary School.

**Keywords:** *competence-based curriculum, colla-petitive pedagogy, collaborative strategy, competitive learning*

## Background Information

Education holds the key in promoting social and economic prosperity of a nation. In Kenya, though, the introduction of Western Education by the colonial government brought with it the misfortune of racial segregation. The proponents of these segregations pointed that different races (Africans, Asians, Arabs, and Europeans) had different levels of social, political and economic development, hence needed a curriculum that would preserve its culture and prepare its people for their "appropriate" roles in the society (Eshiwani, 1990). By offering education to the natives, the colonial settlers majorly aimed at producing "adequately enlightened" farm workers. They opposed any attempts by Africans to aspire to any form of equality, especially academic, with the white man. Ethnic differences were manipulated to subdue the natives (Eshiwani, 1990).

The African post-independent government in 1963 had sought to rectify the irregularities created by the colonial education structure (Ghai & Court, 1974). A commission on education system review was created to address the challenges plaguing the education sector (Ominde Report, 1964). The Commission recommended restructuring of the education system to foster **national unity** and **African socialism**. Changes were suggested in the content of history and geography subjects, which were made to reflect the national cohesion, leading to the introduction of the 7-4-2-3 system in 1964. The 7-4-2-3 system of education lacked the capacity and flexibility to respond to the changing aspirations of individual Kenyans and the labour market needs in terms of new skills, new technologies and the attitude to work (Owino, 1997). According to Simiyu (2001), the 7-4-2-3 policy was criticized for being too academic and two, for promoting elitist and individualistic attitudes among school leavers. The Gachathi Report (1976) indicated that the policy produced many school leavers who could not secure employment hence the skyrocketing unemployment rates reported at the time.

Following the calls by The International Labour Organization (ILO) to change to the education system in order to help **reduce unemployment**, the education system was reviewed to incorporate technical and vocational aspects. The Mackay report (as cited in Muricho & Chang'ach, 2013) indicates how the change saw the introduction of the 8-4-4 education system in 1985. However, Gachathi report had noted with great concern the rising rates of unemployment among school leavers and recommended the restructuring of the education system curriculum to incorporate more aspects of science, mathematics, and technical and vocational subjects (GoK 1976). Both commissions' reports emphasized the integration of practical subjects in primary through to the tertiary levels (Simiyu, 2001). The 8-4-4 system has been criticized for being broad, expensive and burdensome to the learners and parents. It has been implicated in the worst strikes that engulfed a number of schools in Kenya during the year 2001 and the general poor quality of education (Amutabi, 2003). As Muricho & Chang'ach (2013) observe, the nobility of adopting the skill-based 8-4-4 education system somehow dissipated along the way.

In the quest to boost learners' practical skills for the job market, Strengthening of Mathematics and Science Secondary Education (SMASE) project was launched in 1998 as a joint technical cooperation between the governments of Kenya (through the Ministry of Education) and the Government of Japan (Japan International Cooperation Agency - JICA). To cater to the increased demand for in-service education and training on SMASSE projects, Centre for Mathematics, Science and Technology in Africa (CEMASTEA) was then established in 2003. In addition, SEMASE-WECSA (Strengthening of Mathematics and Science Education in Western, Eastern, Central and Southern Africa) was born in 2001 out of a regional conference held in Nairobi Kenya. The overall objective of addressing the challenges in the teaching and learning of mathematics and science was found to be a major cross-cutting issue in the curricula of the member countries in

Africa. In Kenya for instance, practical examinations are a major contributing factor to poor performance in sciences (KNEC, 2019). The dismal performance is attributed to infrequent exposure to science-based practical lessons while other learners have shown apparent disinterest in the subjects.

## Statement of the Problem

Every once in a while, the Kenyan education curriculum is reviewed to adequately address the current challenges. Starting with the education system handed down from the colonial government, the school system has always promoted cut-throat competition motivated by pricey reward for the best performers. The ranking and **reward system** for the **competitive model** is skewed to the top, favoring but a few who manage to reach the top by sheer hard work, stroke of luck or crooked means. Motivated by the desire to beat everybody else, vices such as academic dishonesty thrived. As more schools posted several A's in the national examination results, the quality of education suffered the more as schools and learners got obsessed with scores rather than the quality of the output. The introduction of CBC has been lauded as a timely intervention to salvage the quality of the Kenyan education. Based on the studies that have been highlighted in this study, collaborative learning has been found to increase learners' interest in the learning process and improve their ability to retain information. Through **colla-petitive pedagogy**, learners initiate the learning process, engage their peers, proactively seek for solutions to their problems, look out for the welfare of their fellows, and find their purpose hence are more focused in the learning process.

## Methodology

The methodology for this study included a desktop review of literature touching on the Kenyan education system, how it has transited over the years and reviewed reports on the gains and challenges over the period. Literature on the curricula systems of developed countries namely Japan, Finland, Singapore and Germany were also reviewed to see the challenges their competency-based systems have faced and how they were able to surmount each. The review highlights the advantages of each of these systems with the aim of gaining more insights to make sound recommendations on how to surmount imminent pitfalls that Kenya is likely to face in her quest to implement the competency-based curriculum. In addition, the researchers have also used primary data derived from the performance of selected schools on which the colla-petitive pedagogy was tried. Colla-petitive is a portmanteau of collaboration and competitive learning, which gives the learners the benefits of both collaboration and competitive learning.

## Collaborative Pedagogy

According to Laal and Laal (2012), "collaborative learning (CL) is an educational approach to teaching and learning that involves groups of learners working together to solve a problem, complete a task, or create a product". Collaborative learning promotes group work among learners; the setbacks encountered in the process is borne equally among the members and the success is shared by the members in equal measure. However, some group members may lack the incentive to put more effort into the group work because they know that someone in the group will have to do it. This is a common problem in school group assignments where some group members do not contribute anything constructive during group sessions and only present themselves so their names do not miss in the group report. The weak learners rely on the bright ones to complete the assignment on behalf of the group; they know they will share the score equally and the bright learner cannot risk failing in the assignment.

## Competence-based Curricula from Selected Countries

### Education system in Japan

The levels of literacy in Japan are among the best in the world. According to The Organisation for Economic Co-operation and Development (OECD) Report (2009), less than 14% of 15-year olds do not attain level II of the Program for International Student Assessment (PISA) baseline on reading proficiency, which is way below the OECD average of 19%. Other developed countries like Finland, Korea, Canada, and Shanghai have even lower rates at less than 10%. In mathematics, Japanese students outperform the global average. Only less than 13% of the learners performed below the level II on PISA mathematics. This is way below the global average at 22%, making Japan one of the best countries in terms of numeracy skills at elementary level. The learners perform even much better in science since only less than 11% of them were found to perform at level II, which is less than the global average at 18% (OECD, 2009). These statistics indicate that the Japanese learners are better placed to learn skills that prepare them for the future, especially when it comes to numeracy and applied science.

In a typical Japanese class, the student population adds up to 40 on average. This arrangement helps the teacher identify the strengths and weaknesses of the learner and apply necessary intervention at the right time (Koyama, 2008). Talents are identified and learners are moulded in the right direction after their individual passion. Teachers are actually mentors of the young learners. Collaboration is promoted and peer learning is encouraged. As a result of this arrangement, the **learners enjoy** the learning process because they initiate it and the teacher is only in the class to direct the process (Makia, 2008). Truancy is almost non-existent, learners never report late to school and are genuinely concerned over their peers' welfare.

### Education System in Finland

The Finnish education system is among the best developed in the entire world. The Finnish students have consistently topped the PISA ranking on students' abilities in reading, mathematics and science (OECD, 2013). This background has made Finland one of the most endowed countries when it comes to skilled human resources. Finland has nine years of basic education program that strongly focuses on equity and prevention of low performance/achievement. The system eases as one enters vocational/middle school to prepare for tertiary education. Day care programs and pre-primary education is offered to all with the latter being free and voluntary. More than 98% of all children under six years of age attend these institutions to prepare them for primary education (OECD, 2013; Kauppinen, 2016). Teachers are highly qualified; one is required to have a Master's degree and hands-on experience to be employed as a teacher in the Finnish education system (OECD, 2013).

The learning process in Finland focuses on quality with curricula, policies, acts and decrees, and evaluation criteria all geared towards achieving this singular objective. All parts come into play to support teaching and learning with both vertical and horizontal integrations to facilitate common understanding and enhance access to information needed for new development processes (Sahlberg, 2010). The curriculum is developed in such a way as to facilitate interaction and provide the basis for pupil evaluation and assessment. The entire Finnish education system does not use **ranked evaluation system** to assess learner performance. Instead, the curriculum emphasizes the importance of the goals of learning and the learning process over the content of the course materials. It takes a competence-based approach and balances between academic achievements and the development of the student welfare making the learner future oriented (Kauppinen, 2016).

### Education System in Singapore

In Singapore, the education system greatly underscore holistic development of a learner. Core values that underscore knowledge and skills are given priority in academic pursuit. Singaporeans believe that social and emotional competencies are necessary for any forward-thinking economy. These must be taken care of for any country to prepare its citizenry to address the challenges of the future. Those who have mastered these competencies are well-prepared to recognise and manage their emotions, make rational decisions, develop concern for others, foster long-lasting relationships, and effectively handle challenging situations (Singapore Ministry of Education [MOE], 2018). Singaporean competency-based education system equips the learners with competencies that make them self-conscious, develop a sound moral compass as well as the skills they need to solve the challenges of the future.

The education policy in Singapore promotes learner competency by enabling the learners to develop creative thinking skills through creative content delivery and reduced curriculum content. As is the case with Finland, Singaporean education system lays emphasis on the process of learning rather than the amount of content covered in the syllabus (Tan *et al.*, 2017). Teachers employ pedagogical methods that not only stimulate learner participation but also enhances their capacity to retain the information learned. The learning process gets more attention from both the learner and the teacher than the course content. The use of multimodal approach in content delivery, such as use of comics in teaching mathematics, has been found to “inject fun in the learning process thereby increasing students’ interest in the subject” (Tan *et al.*, 2017).

### Education System in Germany

The German education system is a little bit complicated compared to the other European and even the American system in that there could be as many as five different secondary school systems depending on the career path desired by the learner. In Germany, the K12 system is used just like in the USA. There is a law that makes school attendance compulsory for every child between the ages of 6 and 15 years. Private schooling is not very common as the community believes in a sense of ownership and responsibility over the public school system hence almost all children attend public schools in Germany. Different academic models are used including but not limited to Montessori, Waldorf and Jena systems, especially in private schools (Hainmüller, 2003).

For a long time, the German education system has had a tiered education system that directs the learners to their fields of future career. By age 10, the learners have already been segregated into different tracks to prepare for their future careers. The brightest learners attend *Gymnasium* and are prepared for college. The next tier of learners after the brightest ones attend *Realschule* where they are trained for average and/or better white-collar jobs/career. Finally, *Hauptschule* is for the bottom tier learners who are trained for different trades and blue-collar jobs. Education reforms in Germany has made it possible for the learners to shift from one track to the next, which opens up their potential, unlike in the past when it was nearly impossible to shift from one track to the next (Hainmüller, 2003; Solga *et al.*, 2015).

**Competence-based Curriculum in Africa**

In Africa, the competence-based curriculum was adopted for the first time in South Africa in 1998, following the acute shortage of professionals such as engineers, technicians and artisans (Mulenga & Kabombwe, 2019). In 2005, Tanzania introduced competence-based education, which led to the development of competence-based learning and assessment in secondary education (The World Bank, 2011; Kafyulilo, *et al*. 2012). In 2006, competence-based education was introduced in primary education as well (Woods, 2008 as cited in Mulenga & Kabobwe, 2019). Tambwe's (2017) findings revealed various challenges, including low understanding of competence-based education and training (CBET) concept. About 80% of the respondents showed lack of teachers' on-job training on CBET and implementation of CBET pedagogical skills, inadequacy of support facilities and learning resources, lack of motivation to some teachers due to unfavourable working conditions, high number of learners in classrooms, and poor students' cooperation attitude.

**Challenges of Competence-Based Education and Lessons for Kenya**

A competence-based curriculum requires commitment from all the stakeholders within the education system. There needs to be a close collaboration between the policy makers and implementers who face the challenges on a daily basis so as to plot and implement a plan that will put Kenya on a pathway to sustainability in science and innovation through strengthening of STEM education in the Kenyan curriculum (The World Bank, 2011). To achieve a truly learner-centered system, Kenya must draw lessons from the countries that have gone forth and implemented successful models.

Categorization of schools has been reported in Germany where learners are assessed and enrolled into different schools that will define their future careers. In Kenya, schools are categorized into national, extra-county, county and sub-county schools. Students joining each of these different categories of schools are selected based on their national examination results. In the Finnish education system, learners are not grouped/pooled into schools based on their academic abilities.

Instead, each learner attends the public school closest to their home (Kauppinen, 2016). Kenya should, therefore, put into place structures and policies that will ensure equitable distribution of resources and adequate resourcing of schools to give every learner an equal opportunity to excel in their academics, the school attended notwithstanding.

Since basic education is free in Kenya, every child is expected to attend school leading to large classes. As a result, most slow learners are left behind as the teacher rushes through the syllabus to cover the course content. Since competence-based learning requires individual attention by the teacher to every learner, handling large classes is an imminent challenge that may hamper successful implementation of the program. The policy on teacher to learner ratio should be effectively implemented to ensure that each learner gets adequate attention and guidance from the teacher. Parents/guardians should also be sensitized to be more involved in their children's learning process. The CBC system emphasizes learner-centered approaches to learning, hence the need for a tracking system. Getting learners interested in the process can be enhanced by use of methods that require learner input so they can initiate the learning process.

## Colla-petitive Pedagogy

Colla-petitive pedagogy is a teaching, learning and revision strategy that enhances communication and collaboration among learners through **intra-team collaboration** and **inter-team competition** (colla-petition). This strategy enhances teamwork and concern for one another since all the team members are motivated to ensure that their weakest member performs better than the weakest member of the opposing team. The learners get advantages of collaboration and are motivated to improve competence through inter-team competition. Colla-petitive strategy is an all-encompassing pedagogical method that encourages the learners to be concerned about each other's welfare both within and outside the confines of the learning institution. Much details of this strategy have been discussed in the book, "Colla-petitive Learning and Learner-Centered Evaluation Strategies for Knowledge Retention".

Having carried out a preliminary survey and analysing KCPE and KCSE results from various schools around Nakuru County, Collanet Africa and Skedastic Consultancy Firm observed that most students tend to perform poorly in mathematics and science subjects. A follow up on the performance through interactions with the learners revealed that the likelihood of a learner to perform well in a subject is directly proportional to the positive relationship between the learner and the subject teacher. Many students admitted that the peers and subject teacher, to greater extent influenced their attitude towards mathematics and science subjects. There were cases where the learners reported a total shift in attitude towards a subject given the pedagogical method employed by the subject teacher.

All of the schools that agreed to mount colla-petitive strategy as an alternative pedagogical method have reported marked performance in both internal and national examinations. Learners have reported to enjoy the learning process and even take the initiative to read topics ahead of the teacher. One of such schools is Nyakiambi Primary in Nyandarua County, which realized a positive deviation of 23.46 point average in 2017 KCPE and 22.77 point average in the 2018 KCPE examination results. Vanessa Grant Girls' High School has also applied the colla-petitive pedagogy as an alternative learning strategy in 2018. The school reported a mean score of 7.0 in the KCSE examinations, which was a big leap from the previous year's mean of 5.9 (2017) when the strategy was not in place. Other schools that have reported improved performance include Kambala Primary School, and Kinare Primary School. With these results, we can report with confidence that application of colla-petitive pedagogy can help improve the learning process through development of value systems and skills necessary to master self-drive, grit and confidence.

## Conclusion and Recommendation

Implementation of the Competence-based Curriculum in Kenya is highly welcomed move in the process of making Kenyan education system relevant in addressing the challenges of this time. Kenyan learners need to be prepared for the challenges of the future through education reforms. To avoid falling into the pit of producing lazy scholars and professionals, the education system must inculcate into the learners the core values of hard work, honesty, responsibility, concern for others and synergy. Colla-petitive pedagogy offers a unique opportunity to address the challenges of CBC as the system is being rolled out. It will utilize the locally available facilities and resources, including the already approved textbooks by KICD. By Borrowing from the success of Finland, Singapore and Japan, Kenya has more to gain from the on-job training of teachers to enhance their capacity on the implementation and sustenance of competence-based curriculum in Kenya. This can be accelerated by using the affordable colla-petitive program and guide books for learners, teachers and parents, who are the major stakeholders in the learning process.

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**Article 32**

# Do primary teachers' assessment practices in Lesotho inform learners' learning of mathematics?

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**Abstract**

Assessment is an integral part of teaching and learning process as it provides feedback from which inferences can be drawn and acted upon effectively by both teachers and learners in the classroom. It provides learners with learning opportunities to show what they know and can do. It also fosters growth towards learners' learning of mathematics. The purpose of the study was to establish whether primary teachers' assessment practices inform learners' learning of mathematics. The study followed case study design where few teachers were studied in considerable depth through observations and interviews. Results of the study revealed that teachers were using some assessment strategies like sharing learning intentions, success criteria, peer and self-assessments which were helpful in learning of mathematics though to certain extend. However, teachers did not provide learners with descriptive feedback which inform their learning. Mostly, teachers used symbols to indicate learners' level of understanding which did not help them in improving their learning. Teachers illustrated that with class-size they had, writing performance statements was practically impossible. The study concludes that some assessment strategies used by teachers in assessing learners in mathematics were effective to limited extend and as such did not help learners that much in their learning.

**Keywords**: *Assessment practices, mathematics, learners' understanding, assessment for learning strategies*

**Abbreviations:** *MoET - Ministry of Education and Training; CAP - Curriculum and Assessment Policy*

## Intoduction

Assessment plays an important role in the teaching and learning of mathematics as it conveys in clear and direct terms what the outcomes of learning are. NCTM (1995, p.3) defines assessment as "the process of gathering evidence about a learner's knowledge of, ability to use, and disposition toward mathematics and of making inferences from that evidence for a variety of purposes". Some of the purposes of assessment include informing teachers, learners, parents and policymakers about what learners have learnt.

Assessment is also a tool that leads and informs the teacher when making instructional decisions and at the same time guides and enhance learners' learning. Umugiraneza, Bansilal and North (2017), emphasize that assessments should go beyond merely evaluating what learners can do and cannot do but rather it should concentrate on all activities that teachers and learners do in acquiring information that can be used diagnostically to improve teaching and learning. Mathematical Science Education Board, National Research Council (1993) also asserts that assessment should reflect the mathematics that is most important for learners to learn and should also be designed in ways that will help communicate goals of learning and the products of successful learning.

In the same manner, NCTM (1995) posits that when assessment is an integral part of mathematics teaching, it contributes considerably to learners' learning of mathematics. It further demonstrates that classroom assessment should support the learning of important mathematics and should provide valuable information to both teachers and learners alike. For Mikre (2010), the importance of assessment in the teaching and learning of mathematics is to increase learners' motivation, encourage good study habits and provide feedback that identifies learners' strengths and weaknesses. However, if assessment is not carried out properly, it will not provide teachers with information that will help them adjust their instructional practices and it will also not help in promoting learners' learning.

Lesotho like many other countries also noticed that the assessment that was used in the primary schools was not effective in promoting learners' learning. Furthermore, it was observed that the use of marks and grades encouraged competition amongst the learners rather than improving learners' learning. Hence the Government of Lesotho through MoET introduced CAP in 2009. The policy was meant to transform the teaching and learning as well as the assessment procedures (MoET, 2009). The policy illustrates that instead of "marks and grades, teachers should generate statements about each learner's progress and ability. These will help to know exactly what a learner has learned and is capable of doing, and also indicating areas where remedial work is needed" (MoET, 2009, *v*). The policy further illustrates that assessment should include both summative and formative assessment modes in fulfilling different purposes of assessment. The use of the two assessment modes are such that learners progress from grade 1 to grade 10 through use of formative assessment and at the end of grade 10, they are assessed summatively.

Currently, the school syllabuses for all the grades have clearly stipulated that in assessing learners, teachers should share the learning outcomes and success criteria with learners at the beginning of the lesson, provide descriptive feedback, oral or written, that help learners to identify their strengths and weaknesses, and also make use of self and peer-assessment so as to discover areas for improvement (MoET, 2009).

The main purpose of the study was to establish whether primary teachers' assessment practices inform learners' learning of mathematics. In particular, the study sought to address the following questions:

- Which assessment practices were visible in the teaching of mathematics?
- What are the effects of teachers' assessment practices on learners' understanding of mathematics?

**Conceptual Framework**

The concept of assessment for learning was introduced by Black and William (1998) who noticed that assessment was not informative with regard to identifying learners' strengths and weaknesses and also in assisting them in how they can improve by encouraging learners to actively participate in their own assessment. Assessment Reform Group (2002) defines assessment for learning as the "process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there" (p.1-2). In other words, this definition illustrates that assessment is an activity that can promote learning if it provides feedback that can be used by both teachers and their learners to modify the teaching and promote learning. If assessment is to be informative about teaching and learning, it should happen during teaching/learning process so that modifications can be done on time because if it is done after teaching/learning process, it might not help in correcting the weaknesses seen during the teaching/learning process. For Sadler (1989), assessment that is formative should close the gap between learners' current state of learning and the intended learning. In the context of Lesotho, it has been decided to use formative assessment and assessment for learning synonymously.

For Absolum (2010), assessment for learning is about the understandings and strategies both learners and teachers need in order to involve learners actively in assessment of their own learning and to collect information that will help in deciding on what should be done next to support learners' learning. Following the definition of assessment for learning, there are a number of strategies that have to be employed to achieve the process. In the context of this study, only five strategies of assessment for learning will be discussed as they are the ones advocated for by the Curriculum and Assessment Policy in Lesotho.

**Learning outcomes and success criteria**

According to Rashid and Jaidin (2014), learning intention is defined as "a statement that describes clearly what the teacher wants the learner to know, understand and be able to do in a lesson" (p. 74). Clarifying and sharing learning goals with learners should be done right at the beginning of the lesson in order to articulate, and share with learners, the learning that the teacher intends to achieve in a lesson. For Wilson (2014), when learners understand very clearly what the learning intention is, and what is necessary to meet this intention, they are more able to take control of their own learning. He further illustrates that it can be extremely demotivating for learners not to know what is expected of them. In the study carried out by Rashid and Jaidin (2014) in Brunei, one teacher showed that "Learning objectives are important as they help learners to focus on what they are supposed to learn for that day" (p. 74).

Clarke (2005) in Small (2019) defines success criteria as a "reminder of steps (as in a mathematical procedure) or ingredients which either must be used (as in instructional writing) or could help the learner achieve the learning objective" (p.26). He further iterates that success criteria might be more or less focused on detail (process success criteria) or more or less focused on solutions (product success criteria). When describing the process and the product success criteria, Bosanquet, Radford and Webster (2016) illustrate that process success criteria are all the steps required in order to complete the task successfully while product success criteria describe how learners will know, at the end of the task, that they have achieved the learning intention.

Thus, process success criteria outline in detail the important features of what is to be learned or how learners will go about the learning. In other words, process success criteria make it easier for the learners to monitor their own progress throughout the lesson. They allow learners not only to check that they are on track, but also help them to keep the target in mind throughout the learning process. According Lee (2017), process success criteria can lay out the route for going through a mathematical process or method successfully.

Generally, success criteria whether process or product can enable learners to compare features of their own work with those that have been identified as indicative of success. Thus, if learners' work does not have similar features to those that have been outlined, they can always improve their work by referring back to the success criteria (Clarke, 2005 in Small, 2019). Furthermore, following success criteria ensure success in attaining the learning objective and also ensure quality. In addition, following success criteria helps learners and teachers to identify where understanding of a particular concept has broken down.

Success criteria should be shared and discussed with the learners at the beginning of the lesson so that learners fully understand them. When sharing learning outcomes and success criteria with learners, learners are better informed about their learning and the standards they are aiming for (MoET, 2009). Knowing the learning outcomes and success criteria promote active involvement of learners in the learning process as they keep them on task, and focuses them on the learning outcomes (Brookhart, 2010).

Mathematics is one subject in which a procedure for finding the solutions to problems should be clearly outlined. Hence the importance of sharing success criteria with learners is to help them understand the steps so that they can be able to reach the intended learning. According to Keeley and Tobey (2011), when learners know what the learning goals is they use metacognitive skills to steer their own learning in the right direction, hence take responsibility for their own learning.

Evidence taken from a study carried out by Heritage (2010) showed the importance of sharing the success criteria with the learners. In the study, one teacher demonstrated that:

The transparency that sharing learning goals and success criteria creates, allows for so much growth for both teacher and learners. The learners know I am there because I have a goal for them to reach and I want them to succeed. They also know I take every opportunity to gather evidence of what they know. Formative assessment has not only changed me as a teacher but I believe it has changed the learners as well (p. 6).

Though provision of process success criteria is important, it can sometimes be disadvantageous in that it can provide a series of steps which learners can just follow thoughtlessly and this might discourage learners' critical thinking. Jerome and Bhargava (2015) demonstrate that specifying every single aspect of what is looked for in a learning process may hinder learners' creativity and prevent them from demonstrate their knowledge and skills in a complete different way. They further posit that providing learners with process success criteria may result in learners who do well on the task at hand, but fail to transfer the learning to other topics and contexts.

However, process success criteria are still helpful especially with learners at lower grades who still need to learn about procedures in mathematics. Hence it is important that success criteria are not kept as a secret to the learners and should be made available to them throughout the lesson so that they can keep on checking their work against them whenever need arises.

**Descriptive Feedback**

Descriptive feedback informs the teacher about learners' performance in relation to the learning objective and also helps him or her to adjust his or her teaching practices where necessary in order to align with learners' needs. At the same time descriptive feedback indicates what learners' strengths and weaknesses are and point out precisely what they need to do to improve. Heritage (2010: 12) argues that effective feedback describes the learner's work, comments on the process the learner used to do the work, and makes specific suggestions for what to do next.

For Lee (2006) whether feedback is oral or written, for it to be effective, it must satisfy the following three conditions: learners should know the learning objectives and success criteria, they should also know the extent to which they have achieved the learning objective/success criteria and how to close the gap between what they have done and they could do. In this way, learners get an opportunity to display their thinking, deepen and refine their understanding.

MoET (2009) clearly emphasizes that teachers in Lesotho should move away from traditional ways of providing learners with marks or grades which do not clearly indicate what learners know and what they do not know. Instead teachers are to generate a statement about each learner's progress, which clearly stipulate what a learner has learned and is capable of doing, also indicating areas where remedial work is needed.

Learners usually struggle with understanding mathematical concepts. The provision of descriptive feedback can assist in promoting learners understanding of mathematics in that it clearly points out the strengths and weaknesses of the learners and advice on how the learner can address such weaknesses. If learners can act appropriately on the feedback, they will make a significant progress in their learning.

The study carried out by McMillan, Venable and Varier (2013) revealed that "feedback encouraged learners to reflect on their understanding of what was being learned through revision, and self-assessment" (p. 5). In the same manner, Hattie and Timperley (2007) posit that research evidence shows that providing learners with comments is more effective than providing them with grades or symbols. They further illustrate that one of the influential studies carried out by Page in 1958 showed that feedback in the form of short written comments rather than grades alone significantly improved learners' performance in a test In a nutshell, good descriptive feedback provides learners with opportunities to judge their capabilities against the set standards and to try and close the gap between current and desired performance.

**Self and Peer Assessment**

Self-assessment can be described as an assessment used by learners to reflect on their learning against the success criteria. For Andrade and Du (2007), self-assessment is "a process in which learners reflect and evaluate the quality of their work and their learning, judge the degree to which they reflect explicitly stated goals or criteria, identify strengths and weaknesses in their work and revise accordingly" (p.160). In other words, when learners engage in self-assessment, they make adjustment to their own learning by selecting appropriate strategies that enable them to move forward. In this way, learners become actively involved in the learning process and hence become responsible for their own learning. Thus, learners' self-assessment process marks the transition to independent learning in that if learners are able to monitor their own learning and make some of their own decisions about what they need to do next, they are using metacognitive skills (Brookhart, 2010, p3).

Peer assessment is another strategy of assessment for learning which is effective in the teaching and learning of mathematics. Wilson (2002) in Frankland (2007) defines peer assessment as the assessment of the work of others with equal status. Peer assessment allows learners to talk about and share their ideas. In this way each one of them becomes part of the deliberations and thereby internalizes the language and the ideas used. Engaging learners in peer assessment has numerous benefits in the teaching and learning of mathematics. It allows learners to learn from each other's successes and weaknesses. Through peer assessment, learners tend to learn more deeply as they have a sense of what is being assessed, thus when applying the criteria to someone else's work learners engage in one of the most productive ways of developing and deepening understanding of mathematical content involved in the process (Roberts, 2006). Furthermore, working with peers is more relaxing for other learners than working with the teacher as this creates a non-threatening environment which can promote learning.

For Wiliam (2007), peer assessment has benefits for learners who are providing the feedback as well as those who are receiving it. While learners who receive feedback from their peer get constructive comments about their work, learners who are providing feedback are also forced to internalize learning objectives and success criteria in the context of their peers' work. Lee (2006), illustrates that when learners talk about their learning, they become self-critical and independent.

He further points out that the act of talking about mathematical ideas and concepts make these ideas available for feedback from the teacher, peers or learners themselves. In the process, learners become active agents in appraising and closing the gap between their understanding and the learning objective. However, for successful implementation of peer and self assessments, it is important that learners are trained on how to use these strategies in an effective manner.

Though assessment for learning has been found to have numerous benefits, research shows that it also has some challenges when implementing it in the class. Some of the factors that impact negatively on the use of assessment for learning include large class size and lack of resources. Kapambwe (2010) illustrates that the number of learners in a class influences the way teachers assess their learners. He further highlights that in assessment, large class sizes are viewed as a threat to the quality of assessments provided by the teacher since teachers are likely to provide ineffective feedback to learners due to the amount of time needed to carry out assessment effectively. Furthermore, assessment for learning is criticized for being resource intensive. The said challenges might threaten proper use of assessment for learning.

## Methodology

The study employed a case study research design in which four teachers were studied in considerable depth. In case study, a researcher seeks to develop an in-depth understanding of the case by collecting multiple forms of data. In providing the in-depth understanding, only few cases are studied (Creswell, 2008). This study was set out in three primary schools in Maseru, Lesotho. The target population was mathematics teachers in grades 1 to 4 because these were the teachers who have implemented assessment for learning for more years than teachers in higher grades. The sample consisted of 4 female teachers who were purposively selected from the three primary schools. Teacher 1(T1) was teaching grade 1 which had 74 learners and was teaching at school A. Teacher 2 (T2) was teaching grade 3 which had 68 learners and was also from school A. Teacher 3(T3) was teaching grade 1 which had 76 learners and was from school B while Teacher 4 (T4) was teaching grade 4 which had 42 learners and was from school C. Data were collected through observations and interviews. Each teacher was observed once using observation schedule. The purpose of classroom observations was to establish the teachers' assessment practices used in the teaching of mathematics and the effects these practices had on learners' understanding of mathematics. Interviews were carried out a week after classroom observations. The aim of carrying out interviews was to help the researchers to get the views of the teachers on the impact of their assessment practices on learners' understanding of mathematics.

## Results and Discussion

Qualitative data collected from interviews and observations were transcribed. The transcripts were read, highlighting the most common features which were later sorted out into different groups depending on the similar meaning the portrait.  Data were then classified into two main themes which were related to the research questions. These themes were *assessment practices that were* *visible in the teaching of mathematics* and *effects of teachers' assessment practices on learners' understanding of mathematics*. Details about each of these themes are discussed below.

**Assessment practices visible in the teaching of mathematics**

Assessment practices which were observed during the teaching of mathematics are outlined below.

**Sharing learning objectives**

All the teachers observed shared the learning intentions with the learners at the beginning of the lesson. Teachers would tell learners what they were going to learn about in the lesson.

One of the components of the lesson plan format used in the Lesotho primary schools is a link-in-statement where teachers are expected to share the statement with learners indicating what they are expected to learn in that lesson. Therefore, it was not surprising that all teachers were able to share the learning objective with the learners.

**Sharing success criteria**

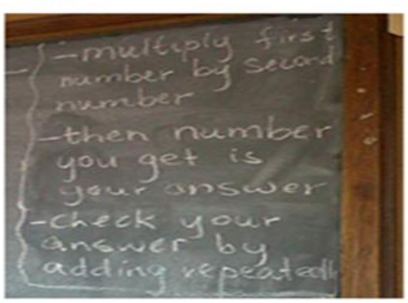
All the teachers observed wrote the success criteria on the chalkboard and read it with the learners at the beginning of the lesson. Teachers kept the criteria for success on the board for the rest of the lesson so that learners could keep on checking their work against them.

When commenting on the importance of success criteria, T4 illustrated that: *I write the success criteria on the board, read them with the learners, the steps in the success criteria make the learning path to be very clear…*

On the same issue of the importance of success criteria, T2 alluded that *learners are now able to check their own work through use of success criteria, and where they do not understand they are able to tell me where the problem is*.

All teachers who participated in the study seemed to understand the importance of using the success criteria. They were using the process success criteria which are acceptable with learners in lower grades. The only problem that was observed was that the success criteria provided were not detailed enough to guide the learners through the process. The figure below shows an example of such success criteria used in one of the classes observed where the learning intention was to 'multiply a two-digit number by a one-digit number'.

Figure 1



**Provision of descriptive feedback**

One out of four teachers observed provided learners with descriptive feedback in the form of oral comments and symbols while the rest of the teachers were only using symbols to show the level of learners' achievement.

Commenting on the importance of using both performance statements and symbols in assessing learners, T4 said that "*the statements when used with symbols help me to know exactly who and where the learner needs help. I now know learners in my class who need my help and these are the ones that I normally target at*".

During interviews other teachers indicated that they did not provide learners with descriptive feedback because of the large classes they teach. Commenting on the use of descriptive feedback, T1 said: *with a large class like mine it takes a lot of time to write statements for each learner.*

Similarly, T3 also exclaimed that ... *for example in large classes we take a week or more to write performance statements for every learner when we administer formal assessment".*

These quotations show that providing feedback that illustrates the strengths and the weaknesses of each learner in large classes is impractical. This finding reinforces the results from Kapambwe's study (2010) which illustrated that large classes are a threat to provision of quality feedback and also influence the way teachers assess.

**Self – assessment**

During classroom observations, some learners were seen checking their work against the success criteria and would also take some time to reflect and correct their work even before they could be checked by the teacher. This was evident when one learner who was about to hand in his work to the teacher for marking made a remark "*aceeeer*" and immediately went back to his seat to make some corrections. This shows the importance of the success criteria in promoting self-assessment as was illustrated by Clarke (2005) in Small (2019). Without the criteria for success, learners would find it difficult to check their own work unless they are provided with exemplars of what a good work looks like. However, some of the learners whose teachers participated in the study seemed not to know how to self-assess using success criteria as they were stuck.

**Peer – assessment**

In all the classes observed learners were seated in small groups, and the first learner to finish the work would help other members of the group voluntarily since they were not provided with guidelines on how to assess their peers. Hence learners were not providing their peers with detailed explanation of the process rather, they showed them the correct solutions and in other situations they were actually writing the work for them.

**Effects of teachers' assessment practices on learners' understanding of mathematics**

Under this theme, the effects of teachers' assessment practices in promoting learners' understanding in mathematics will be looked at.

**Sharing learning objectives**

Classroom observations revealed that sharing learning objectives with learners at the lower grades did not have much impact on their learning. Some of the learners were not even listening to the teacher when sharing the learning objectives with them and as a result did not know the purpose of the lesson. However, teachers continued to share the learning objectives with their learners despite the fact that learners did not pay much attention to them. Probably teachers continued to share learning objectives with learners because they are mandatory as per the lesson plan format.

**Sharing success criteria**

Sharing success criteria seemed to have positive impact on learners understanding of mathematics especially on mastering the process (procedure) for finding the solution. Some learners were able to compare their work against the provided criteria and did the necessary corrections before handing in their work to the teacher for marking. In the process, they seemed to be thinking about their work. However, some learners still needed some guidance on how the success criteria could be used to improve their understanding of mathematics.

**Descriptive feedback**

The results of the study showed that feedback provided by most teachers was not descriptive enough to show learners' strengths and weaknesses. It did not indicate what the learners knew, did not know and how they could improve on their weaknesses. The learners in T4 class showed a considerable improvement on their work after attending to the comments provided by the teacher. The symbolic assessment used in most classrooms seemed not to have any positive impact and learners had already given them their own interpretations.

**Self and peer assessment**

Self-assessment seemed to have a positive effect on learners' understanding of mathematical problems. These learners were able to correct their mistakes using success criteria even before the teacher could tell them to do so.

**Conclusion and Recommendations**

Teachers who participated in the study incorporated some assessment for leaning strategies in the teaching of mathematics. The mostly used strategies were 'sharing of learning objectives and success criteria' though sharing learning objectives with learners did not have any impact on their learning. However, the use of success criteria seemed to have positive impact on some learners though some success criteria were not well refined. If teachers could be trained on how to develop clear and elaborate process success criteria, this could help in promoting learners' learning. Furthermore, teachers should also train their learners on how to use the criteria for success in checking their own work.

In general, teachers in this study were not providing learners with descriptive feedback which shows the learners their strengths and weaknesses and how the weaknesses could be rectified. Where descriptive feedback was used, learners showed some understanding of what they were doing. This shows that if real improvement in learners' understanding of mathematics is to be achieved, teachers should be encouraged to provide learners with comments whether oral or written that guide learners towards achieving the intended learning outcome. In the case of large classes, teachers could provide learners with oral comments so that learners would know where they went wrong and how they could correct their mistakes. As for the feedback provided symbolically, this should be discouraged as these symbols do not convey any meaning about learners' strengths and weaknesses.

Though teachers in the study did not fully make use of peer and self assessment, these if properly used, could have a positive impact on learners' learning. In the case of Lesotho primary schools where teacher-pupil ratio is high, the use of peer and self-assessment can also reduce teacher's workload. Hence teachers and learners should be thoroughly trained on the proper use of these strategies.

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**Article 33**

# Quantum mechanics symbology: How does it affect students' understanding of introductory quantum mechanics concepts?

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**Abstract**

The purpose of this study was to investigate students' understanding and application of introductory quantum mechanics symbols and the influence that these symbols have on such activities as interpretation of concepts, and problem solving in this field of study. The investigation was conducted at Mukuba University, Kitwe, Zambia. A total of twenty (20) undergraduate third year Physics students were randomly sampled and the symbol sense framework, as suggested by Arcavi (1994), in which, students' levels of symbolic thinking and understanding of what, why and when to use symbols, including an aspect of some symbolic quantum structures were investigated using questionnaires and through focus group discussions, guided the framework. Our research findings indicated that Quantum Mechanics symbols directly affected students' understanding of Introductory Quantum Mechanics concepts, due to; instructors' failure to fully explain what most of these symbols mean; lack of adequate and updated textbooks in the libraries and bookstores; different textbooks using different symbols to mean the same things; failure by students to form visual images as communicated by most of the symbols; less time apportioned to quantum mechanics classes, despite it being counter intuitive, abstract and challenging; insufficient resources to assist students grasp the meaning conveyed by symbols in different situations; and, pedagogical matters relating to its teaching and learning. These findings and results are consistent, and confirm what other researchers in other places have also found. Recommendations that came out from the study include; instructors to be spending enough time to fully explain the symbols; employment of conceptual models and teaching aids like PHETs simulations; procurement of enough, updated and modern textbooks; and the strengthening of pedagogical teaching and learning issues in dealing with the abstract nature of this field and its symbols, would add value to promoting a quantum symbol friendly environment.

**Keywords:** *Symbology, Symbol, Introductory Quantum Mechanics (IQM), Notation, Concepts.*

## Introduction and background

In this investigation we bring out conceivable obstacles to learners' understanding of Introductory Quantum Mechanics, as a consequence of the use of symbols during quantum mechanics instructions. Cobb (2000) defined symbols as "any situation in which a concrete entity such as a mark on paper, an icon on a computer screen, or an arrangement of physical materials is interpreted as standing for or signifying something else." Language is itself a system of symbols and rules that enable us to communicate (Harley, 2001; Dewey, 1910).

Past researches, especially done in the field of mathematics, have revealed that illiteracy of symbols is an impediment to students' understanding of the subject (Bardini and Pierce, 2015). As it is in mathematics, without appropriate apprehension and comprehension of symbols in quantum mechanics, it would be very difficult for students to fully understand and appreciate relations and transformations at the quantum levels of matter and energy.

A symbol's ability to bring out meaning and communicate an idea depends on how the interpreter understands the symbol (Mingers and Willcocks, 2014) and in this context, to understand means "to grasp a meaning, to identify a thing in a situation in which it is relevant" (Dewey, 1910). If learners understand and adequately communicate through symbols and relevant notation in a field of study, then their accomplishment and achievement is highly likely to improve (Rubenstein & Thompson, 2001).

One of the hindrances envisioned in this investigation is the use of symbols in introductory quantum mechanics. Adu and Olaoye (2014) acknowledge that the abstract and hypothetical nature of symbols can be an obstacle to learning. This is so because symbols are part and parcel of the framework of communication, but, their incomprehension and unfamiliarity may result into learners losing confidence and thus, acquire a negative conception about a subject (DeLoache, 2004; Pimm, 1995).

For example, the wave function, symbolically denoted by the Greek letter $\psi$ or $\Psi$ (lower-case and capital Psi) represents the probability density for a particle to be measured in certain locations (Born, 1926). For a quantum system at a particular position and time in space, this is symbolically shown as $\psi(x,t)$. When this is symbolically expressed as having effective mass m and charge density Q distributions, these are written as; $m|\psi(x,t)|^2$ and $Q|\psi(x,t)|^2$ in space respectively.

Therefore, the main purpose of this investigation was to pick up students' insights with regards to how symbolism affects their conceptualisation of introductory quantum mechanical concepts. It also sought to bring out how they interpret the symbols in their pursuit to understand some unfamiliar abstract phenomena. Furthermore, effort was made to explore how symbolism influences their problem-solving strategies.

**Problem statement**

Without gaining the knowledge of concepts and know-how in the skill of discernment of symbol meanings, the study of Mathematics and also introductory quantum mechanics would be meaningless (Moschkovich, 2010). This demands that students become competent in the operations, computations and usage of the necessary symbols. This field, Introductory Quantum

Mechanics, contains unfamiliar symbol notations and conventions as compared to classical mechanics that students are familiar with.

However, many researchers and instructors have observed that many difficulties in mathematical related subjects, which of course include Introductory Quantum Mechanics, are as a result of students' failure to understand and manipulate symbols (Driscoll, 1999; Stacey et al, 1999); Gray et al, 1994; Keira, 2007; Kinzel, 1999).

Learners are often times required to unpack the meaning contained in a symbol or symbolic formulation, failure to which they would resort to purposeless and meaningless usage of symbols, which would hinder their further conceptualisation of the intended communication, resulting in poor performance (Chinn, 2016).

**Aim of the study**

The aim of the study was to;

- Explore the challenges that students face in understanding introductory quantum mechanics, with regards to its symbols.
- Investigate how students' conceptualization and problem-solving activities are affected by symbols in introductory quantum mechanics.
- Use research, to try and come up with teaching strategies which lecturers of introductory quantum mechanics would employ in order to address the effect of symbolic obstacles.

**Research questions**

- What challenges do students face in understanding introductory quantum mechanics, with regards to its symbology?
- How are students' conceptualization and problem-solving activities affected by symbolism in introductory quantum mechanics?
- What teaching strategies should introductory quantum mechanics lecturers employ in order to address the effects of symbolic obstacles?

**Significance of the study**

The significance of this study lies in the fact that it contributes to the comprehension of challenges that students and lecturers face in the learning and teaching of introductory quantum mechanics by way of the symbols encountered. It also looks into, and investigates how students see, apprehend and interpret the symbols. Insights into how students conceptualize the different symbols in diverse settings are also encountered and discussed, to which instructional strategies for dealing with the effects of symbolic obstacles are suggested.

**Theoretical framework**

The theoretical framework used for this study is adopted from Arcavi's (1994) notion of developing and using symbol sense in mathematics, that is, in this investigation, applied in

Introductory Quantum Mechanics, which was initially based on the lecture delivered at the international seminar, "Reasoning, Explanation and Proof in School Mathematics and their place in the Intended Curriculum," held in Cambridge, UK, in October 2001, under the auspices of the Qualifications and Curriculum Authority (QCA). The table below shows several examples from Arcavi (1994) framework of behaviours that illustrate symbol-sense:

| **Examples of behaviours that illustrate symbol-sense** |
|---|
| 1. Making friends with symbols. |
| 2. Manipulations and beyond; reading through symbols, |
| 3. Ability to choose possible symbolic representations and to replace them if the first proves useless for problem solving. |
| 4. Realizing that a symbolic expression is needed and the ability to engineer it. |
| 5. Understanding different roles played by symbols. |
| 6. Possessing flexible symbol manipulative skills, |
| 7. Understanding the need to continuously check symbols meaning and compare with one's expectations and intuitions. |

*Table 1: Arcavi's Symbol-sense Framework*

Zorn (2002) adds to this list, the ability to extract meaning and structure from symbols. Another view from Wu (2009) is that communication of ideas is feasible if symbolic systems are understood and operations between systems could be used to deepen symbolic understanding.

**Methodology**

**Research design**

In this investigation a mixed method approach was used, implying that both qualitative and quantitative ways of gathering and analysing data were employed (Creswell, 2013). The reason for combining the two research methods was to gain a much better understanding of the problem under investigation that neither of the methods would have accomplished alone. Hence, a questionnaire was administered, and recorded interviews were conducted in form of focus group discussions. Using these methods, learners were granted time to freely discuss and write down the difficulties they meet in using introductory quantum mechanics symbols.

The completed questionnaires were analysed using SPSS, while the recorded interviews were first transposed, decoded and meanings cyphered, with follow up questions were necessary.

**Sample group**

Mukuba Universities in Kitwe, Zambia, was appropriately selected merely because the researcher had learnt and taught there, and that is where the challenge with introductory quantum mechanics symbolism was experienced. An assumption was initially made that, similar challenges may be encountered in other universities as well, and sure enough, literature review (Arcavi, 1994; Arcavi, 2005; Bardini, et al, 2015; Heeffer, 2013; Landy, 2010) verifies that this assumption is true.

**Pilot study**

A pilot study investigation to ascertain that quality was adhered to in this study was conducted. This also ensured that the research tools and processes were perfected before the main study was done. This pilot study was conducted, guided by the advice of Zailinawati et al (2006), and Stewart (2011), who defined a "pilot study" as a small study to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study.

**Validity of study**

To ensure validity, thus, making the research officially accepted, well-grounded and justifiable (Cambridge Advanced Learners' Dictionary), the focus group questions, and the questionnaires were evaluated and assessed by three physics education research experts who furthermore aligned it with the recommendation from the symbol-sense framework, as advised by Arcavi (1994).

**Reliability of the instruments**

To ensure reliability of research instrument, the questionnaire, thus, the degree to which they produce stable and consistent results, some students were asked to complete the same questionnaires two times with an interval of one week. Afterwards, the results were compared and were found to be stable and consistent with the previous results.

**Data collection**

Two (2) questionnaires consisting of both open and closed ended statements, and symbology, on introductory quantum mechanics symbolism, were given to selected undergraduate students to complete. These students were randomly sampled as advised by Creswell (2013).

Some focus group discussions were also conducted (questions in Appendix II). Data collected from these instruments was analysed through major themes and also using SPSS.

**Results**

Below is a table depicting the gender of the respondents who answered the two questionnaires:

| Gender | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Female | 5 | 25% | 25% | 25% |
| Male | 15 | 75% | 75% | 100% |
| Total | 20 | 100% | 100% | |

***Table 1**: Depicting Gender of Respondents in this investigation*

This table shows that 75% of respondents who answered the questionnaires were males, and 25% were females.

When enquiring whether symbolism is an important issue for consideration in Introductory Quantum Mechanics, below is a table showing the results from the respondents:

| Rating | Frequency | Percent | Valid Percent | Cumulative Percent |
|---|---|---|---|---|
| Strongly Agree | 10 | 50% | 50% | 50% |
| Agree | 8 | 40% | 40% | 90% |
| Undecided | 2 | 10% | 10% | 100% |
| Total | 20 | 100% | 100% | |

***Table 2**: Depicting responses to symbolism as an important issue for consideration*

This table shows that 50% strongly agreed, 40% agreed, while 10% were undecided.

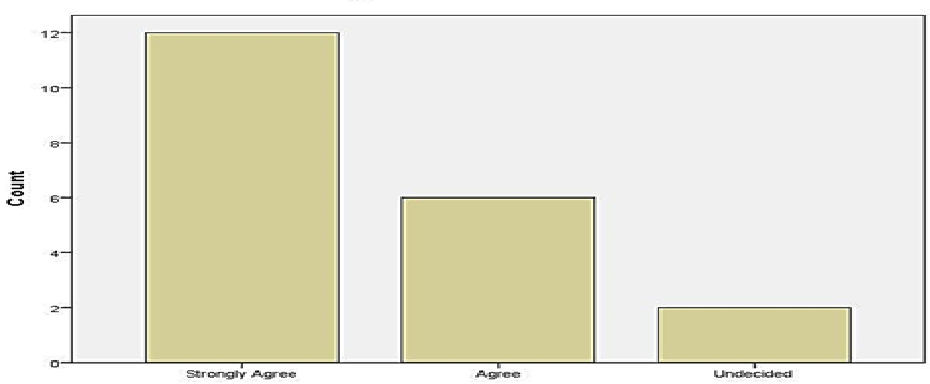
Conclusion: This result indicates that the majority of students, 90% agree with the proposition that symbolism is an important issue that should be given special consideration in Introductory Quantum Mechanics.

When students were asked to indicate whether they have difficulties with symbolism in Introductory Quantum Mechanics, the result that came out was as depicted below:

(NB: In all these figure, count represents the number of individual respondents to particular questions.)

(i) Difficulties with Symbolism of Introductory Quantum Mechanics

*Figure 1: Depicts responses on whether they have difficulties with Symbolism of Introductory Quantum Mechanics*

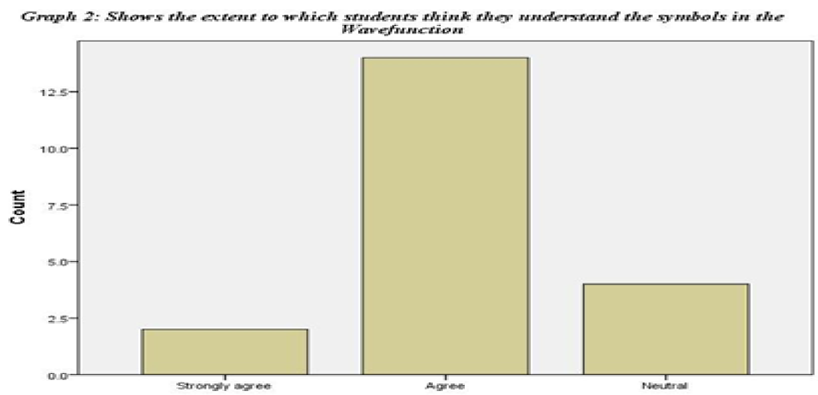



This result shows that, 65% (13 students) indicated that they have difficulties with symbolism; 25% (5 students) were undecided, and only 10% (2 students) indicated that they don't have difficulties.

Conclusion: The majority indicated that they have difficulties. This confirms the researchers' hypothesis that most students have problems in understanding Introductory Quantum Mechanics symbols, and these problems might negatively affect learners' performance in the course.

When required to indicate the level at which they think they understand the meaning and symbols in the wave function, $\psi(x,t)$, the following were the results;

(ii) Wavefunction

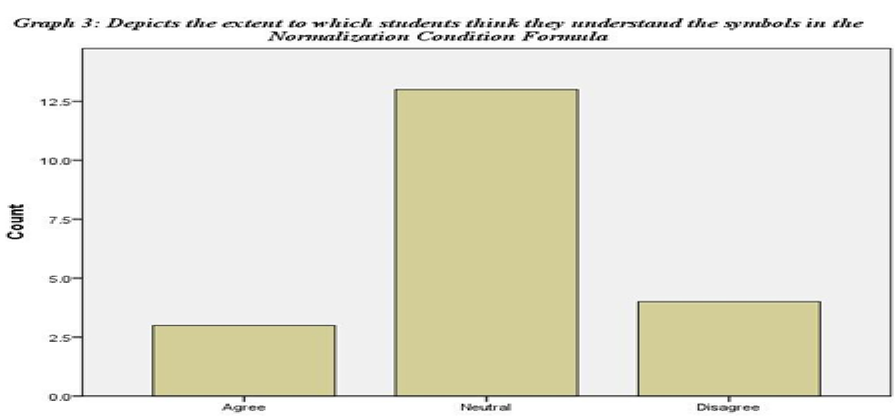



This shows that, 70% (14 respondents) indicated that they do understand the symbols; 20% (4 respondents) were neutral, and only 5% (1 respondent) indicated that he doesn't understand the wave function and its symbols.

Conclusion: Most students who participated in this investigation, understand the symbols and meaning of wave function in Introductory Quantum, hence, this is a positive result

When asked to indicate the level to which they think they understand the symbols in the Normalization condition, $\int |\psi(\mathrm{r},\mathrm{t})|^2 \mathrm{dr} = 1$ , the following were the results;

(iii) Normalization Condition Formula

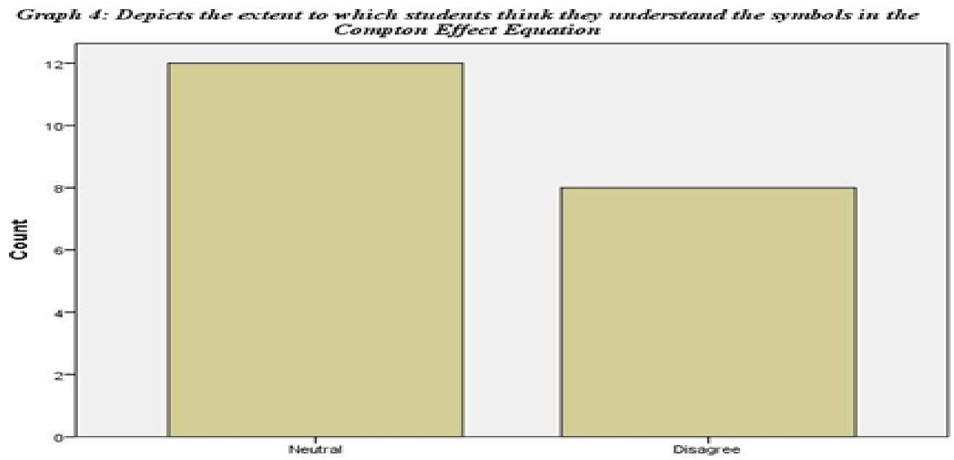



The graph shows that, 15% (3 respondents) indicated that they understand the symbols; 65% (13 respondents) were neutral or not sure; and only 20 % (4 respondent) indicated that they don't understand the symbols in the normalization condition.

Conclusion: This result reveals that most students who participated in this investigation have not fully grasped the concept of the normalization condition.

When asked to state the level to which they think they understand the symbols in the Compton effect formula, $\Delta\lambda = \lambda^{'} - \lambda = \frac{h}{m_0 c}(1 - \cos\phi)$, the following were the results;

(iv) Compton Effect Equation

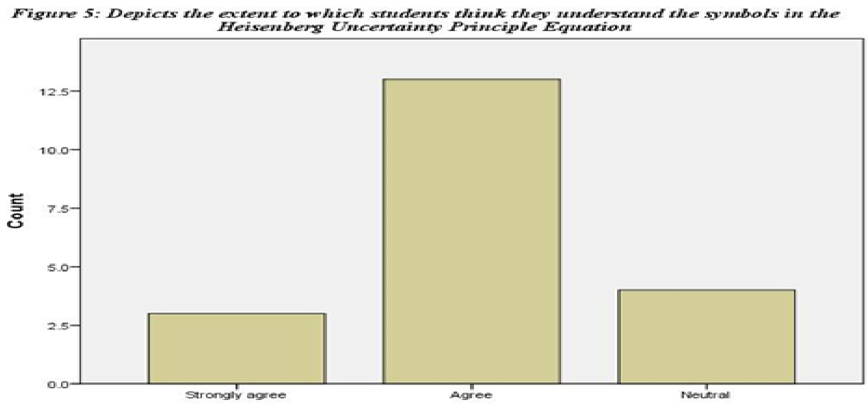



This graph shows that 60% (12 respondents) were neutral or undecided and 40% (8 respondents) indicated that they do not understand the symbols in the Compton Effect formula.

Conclusion: Judging by this result, we can safely conclude that most students do not really understand what the symbols in the Compton Effect Formula represent.

When required to show the level to which respondents think they understand the symbols in the Heisenberg Uncertainty Principle equation, $\Delta x \Delta p \geq \frac{\hbar}{2}$ , the following were the results;

(v) Heisenberg Uncertainty Principle

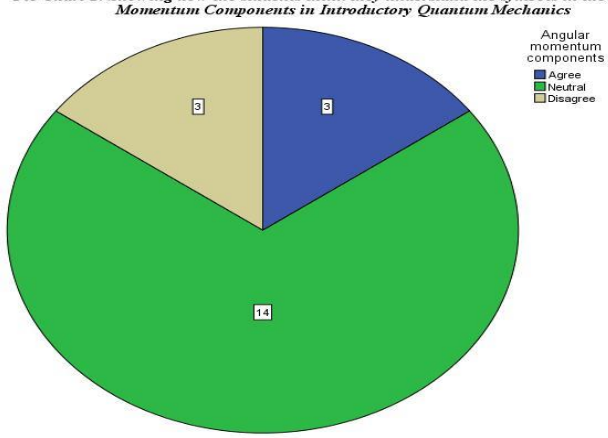


The results are as follows, 15% (3 respondents) indicated that they strongly understand the symbols; 65% (13 respondents) understand the symbols, 20% (4 respondents) were neutral.

Conclusion: The majority understand the meaning and symbols in the Heisenberg uncertainty principle equation.

When asked to show the level to which the respondents think they understand the symbols in the Angular Momentum Components, $L = r \times p = \begin{vmatrix} e_i & e_y & e_z \\ x & y & z \\ p_x & p_y & p_z \end{vmatrix}$, the following were the results;

*Pie Chart 1: Showing how the students think they understand the symbols in the Angular Momentum Components in Introductory Quantum Mechanics*

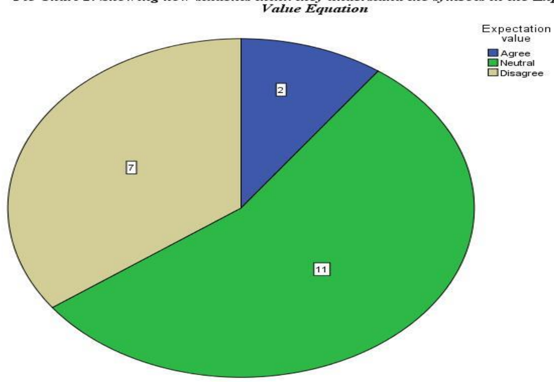



This result shows that, 15% (3 respondents) indicated that they understand the symbols; 70% (14 respondents) were not sure if they understand, and another 15% (3 respondents) indicated that they don't understand the symbols.

Conclusion: Majority are not so sure if they understand what the symbols in the Angular Momentum Components really mean.

When asked to show the level to which the respondents think they understand the symbols in the Expectation Value Equation, $\langle A \rangle = \langle \psi | A\psi \rangle \equiv \langle \psi | A | \psi \rangle$ , the following were the results;

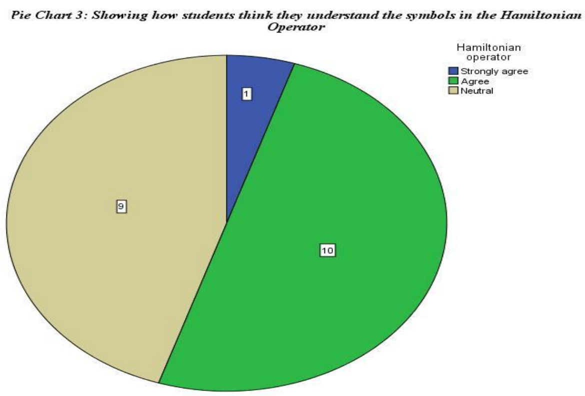
*Pie Chart 2: Showing how students think they understand the symbols in the Expectation Value Equation*



Showing that, 10% (2 respondents) indicated that they understand the symbols; 55% (11 respondents) were neutral, while 35% (7 respondents) indicated that they don't understand the symbols.

Conclusion: This result shows that the majority do not understand the meaning and symbols in the Expectation Value Equation.

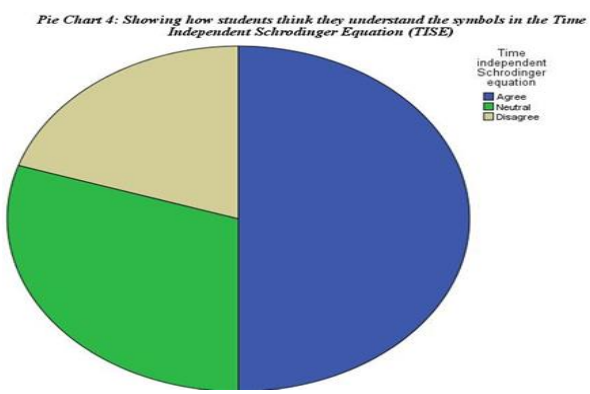
When asked to show the level to which they think they understand the symbols in the Hamiltonian Operator, $H = -\frac{\hbar^2 \nabla^2}{2m} + v(r,t)$, the following were the results;




This pie chart shows that, 5% (1 respondent) indicated that they strongly understand the symbols; 50% (10 respondents) indicated that they understand, while 45% (9 respondents) were neutral.

Conclusion: The results shows that almost half the number of respondents do understand the symbols, and the other half is not so sure if the understand.

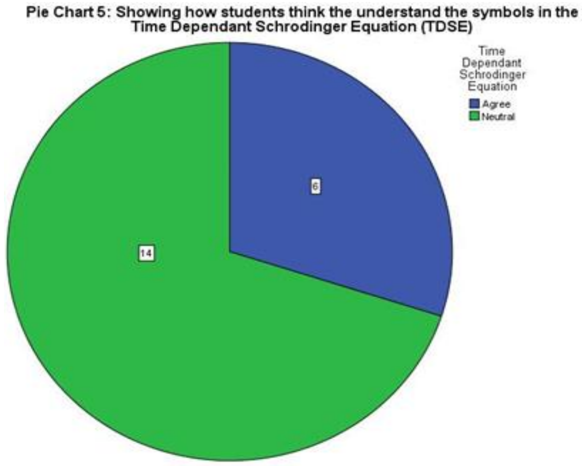
When asked to show the level to which they think they understand the symbols in the Time Independent Schrodinger Equation, $H\psi(r) = E\psi(r)$ , the following were the results;




The results show that, 5% (1 respondent) indicated that they strongly understand the symbols; 50% (10 respondents) indicated that they do understand, while 45% (9 respondents) were neutral.

Conclusion: The result indicates that almost half the number of respondents do understand, and the other half is not so sure if the understand.

When asked to indicate the level to which they think they understand the symbols in the Time Dependent Schrodinger Equation, $i\hbar\frac{\partial}{\partial t}\psi(r,t)=\left(-\frac{\hbar^2\nabla^2}{2m}+v(r,t)\right)\psi(r,t)$, the following were the results;




This result shows that 30% (6 respondents) indicated that they understand the symbols, while 70% (14 respondents) were neutral or not so sure if they understand.

Conclusion: This result shows that the majority of respondents are not so sure if they understand the symbols in the Time dependent Schrodinger equation.

## Data analysis and discussion

### Qualitative data

During the interviews and focus group discussions, respondents were given time to express their opinions and thoughts about Introductory Quantum Mechanics symbols.

Among the common issues that emerged, for students' failure to grasp and understand the meanings of some symbols, and often times, their inability to use the symbols appropriately was due to, among other reasons; the instructors'/lecturers' failure to fully explain what most of these unfamiliar symbols in Introductory Quantum Mechanics really mean or represent. As a result of this, most students merely use these symbols even without understanding them, a situation often referred to as "symbol pushing."

The lack of adequate and updated textbooks and other resources in institutions of higher learning, public libraries and also in bookshops. This, according to the respondents, denies them the ability to easily transfer and connect symbolic information from the abstract nature of Quantum Mechanics into reality, on their own.

Another reason given was that, lecture notes and textbooks alone do not provide thorough explanations regarding how, what and why particular symbols are employed to develop some quantum mechanical concepts and problem solving steps and procedures.

Highlighted also is the fact that different textbooks use different symbols to express, at times, the same meaning. A good number of students raised the issue of switching symbolic representations between the old and latest textbooks; between books written by European writers and those written by American writers, as being another challenge.

Some students interviewed said that there seem to be no one conventional symbol system between old and new quantum mechanics textbooks; instead, symbol systems are changed along and within textbooks according to context of where, who and when the textbook was written.

Other students included the mathematical reasoning behind the symbolism as another challenge, for example, when learning eigenvalue-eigenvector equations and other quantum mechanical formalisms, students are expected to understand that an expression such as $\widehat{H}\psi$ or $\hat{S}\phi$ does not represent multiplication as they have been previously taught, but rather, an operation on a vector or function that transforms it into another vector or function.

The failure by students themselves to form visual images as communicated by most of these symbols, which then results in their inability to assign meanings to them and thus, negatively affecting their perception of the different quantum phenomena.

Less time apportioned to quantum mechanics classes. From the students' point of view, unlike classical mechanics which has concrete representations, quantum mechanics is more counter-intuitive and abstract in nature, and hence, it requires more time for learners to understand its conceptual language fully.

Finally, through these interviews and discussions, it came out that pedagogical matters relating to teaching and learning of Introductory Quantum Mechanics was another challenge. There was a common acknowledgement among the respondents that the traditional teaching and learning methods used by most lecturers do not fully explain and enhance learners' understanding of the various quantum mechanics symbols.

**Quantitative data**

As depicted and illustrated from the graphs and pie charts above, it can be seen that the majority of respondents have difficulties in understanding and grasping the meaning of some specified symbols.

The first item from the questionnaire showed that 90% agreed that symbology of introductory quantum mechanics is an important issue which should be given special attention, if performance in this study area is to improve.

The second item, showed that the majority again indicated that they do experience difficulties when dealing with symbolism in introductory quantum mechanics. Thus, from the respondents, 18 indicated facing difficulties, and only 2 indicated that they do not have difficulties.

For specific individual symbols, appearing in equations and expressions, most respondents indicated having difficulties with the Compton Effect Equation (CEE) symbols, the Expectation Value Equation (EVE) symbols, the Normalization Condition Equation (NCE) symbols, and the Angular Momentum Components (AMC) symbols.

Symbols that were indicated to be less of a problem to grasp and understand, include those of the, Wavefunction expression, Heisenberg Uncertainty Principle (HUP) symbols, Hamiltonian Operator symbols, the Time Independent Schrodinger Equation (TISE) symbols and those for the Time Dependent Schrodinger Equation (TDSE) symbols.

## Conclusion

These results are in harmony with, and confirm what other researchers in other places have found (Worthington et al, 2003; Arcavi, 2005; Yetkin, 2003; Murray, 2009). These researchers also observed that students find it difficult to understand the symbolism, for example in Algebra, and this has a likelihood of resulting in poor performance in the area of study.

It was also clear from this investigation that many students in Introductory Quantum Mechanics in general, lacked some of the desired components of symbol sense that Arcavi (1994) suggests are so important to the broader topic of sense-making. However, it is not too late for institutions of higher learning that offer this and similar courses to begin helping students build positive symbol sense, by engaging them in teaching and learning activities that promote it.

Being aware of learners' difficult and the source of the difficulties, and designing instructions to minimise or diminish them, are important steps in achieving meaningful learning. Student difficulties in understanding symbols in Introductory Quantum Mechanics can be reduced by using appropriate representations and explanations of symbols depending on the given problem context; creating learning environments for understanding symbols that help learners build connections between their formal and informal knowledge; and helping learners connect procedural and conceptual knowledge of symbols in a field of study.

It may not be helpful to just tell learners what a symbol mean, but it's better to understand that learners have their own interpretations and understanding based on their own experiences with symbols (Stacey et al, 1999). Building symbol sense can therefore, help build learners' fluency with the complicated and often abstract symbolic language of Introductory Quantum Mechanics.

## Recommendations

From these findings, the following recommended are made;

- Where necessary, the lecturers to spend enough time to fully explain the symbols, so that the learners develop a conceptual understanding of the subject matter;

- Enough modern and updated Quantum Mechanics textbooks be procured so that students can have enough time to understand the symbolism and be able to attach these to concepts, during and outside the lecturer hours;
- Conceptual models and teaching aids like PHETs simulations be employed in teaching and learning so that the meanings of the symbols are attached to visual and concrete ideas.
- The bridge between classical and quantum mechanics be well defined and explained, so that concepts from one field are not confused with those of the other.
- The pedagogical issues in teaching Introductory Quantum Mechanics be strengthened so that the abstract nature of the field area, and its symbolism communicate effectively and meaningfully
- There is need for more research to be done, so that instructions are designed that would help students to construct meaningful ideas out of the various symbols of introductory quantum mechanics.

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**Strand 5# ICT Integration in STEM Education**

1.Resources and Solutions for STEM Learning
2.Fun Learning STEM through Games and Robotics
3.Link School and Industry on STEM Education

**Article 34**

# A digital content development concept using local teachers for effective integration of ICT in education

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**Abstract**

Skilling for the future (S4F) is a project that was born out of the realisation that open-source digital learning materials were not enabling the learner to relate classroom knowledge to his/her immediate environment. This is because Open Education Resources used examples and language accent for the country for/from which they were originally developed. The project sought to digitise Mathematics, with an aim to improve learning outcomes as one of the poorly done subjects on the curriculum menu. This paper presents the methodology used to digitise S.1 Mathematics locally and the preliminary results from the trial of the digitised materials, a product by teachers and programmers that never had prior experience in digital content development.

**Key Words:** *Digital content, eLearning, ICT integration, Interactive learning, Learner-centered digital content*

## Background

Mathematics is one of the traditional subjects on the Ugandan curriculum since the introduction of education. In our daily life, mathematics is greatly used by all. On the school curriculum, mathematics is an important subject vested with skills for interpreting information in medicine especially the dosage, interpreting the information of quantitative nature that is presented in newspapers, magazines and national reports (Breslich, 1966). Through this subject the learner acquires knowledge and skill to interpret complicated numerical data, to understand quantitative studies of social phenomena and to recognize fallacies in conclusions (Breslich, 1966). This is imperative for every individual. This, therefore, makes mathematics an important subject for the comprehension of national messages and reports that are important for the livelihood of every citizen. At a higher level, mathematical models are used to make predictions in education research and statistical inferences in all sectors.

Students of mathematics do not pick all these skills at a single stage. The curriculum allows the learners to develop these skills over a period of time throughout the different stages of the academic ladder. With the spiral design of the curriculum, the learner keeps building on the already acquired simple skills as they progress to more complex applications of the same skills in different and more complex situations (Dowding, 1993). This directly means that the learner needs to fully understand the simple skills taught at lower levels of education if s/he is to fully understand and apply the complex mathematical concepts at a later stage.

The traditional education system was based on the concept of 'knowledge transfer' from the teacher to the learner. Digitisation of education has ushered in an era of democracy of knowledge-making education a collaborative, self-driven interaction between learners and teachers (Channan, 2017). A shift from a traditional system to a new system requires teachers to take on a new set of skills. One of such skills is the ability to prepare and deliver a collaborative and self-driven lesson with the help of technology. A teacher from a traditional classroom in Uganda needs great support to be able to combine content knowledge, pedagogical knowledge and Technological knowledge as he/she prepares a lesson to be delivered using ICT (UNICEF, 2017).

At the moment, mathematics is one of the best-done subjects at pre-primary and primary levels of education (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, The Acheievement of learners in Early Grade Reading in selected district of Uganda: Baseline report, 2016); (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, The Achievement of S.2 Students in Uganda in English Language, Mathematics and Biology, 2013); (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, The Achievement of S.2 Students in Uganda in English Language, Mathematics and Biology, 2014); (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, The Achievement of S.2 Students in Uganda in English Language, Mathematics and Biology, 2015). However, as pupils progress through, the percentage of learners who are rated proficient in the subject keeps reducing. The percentage of learners proficient in mathematics is relatively high when learners join secondary education. As they progress, many develop bias towards the subject and get demotivated. This is partly because of their interactions with fellow learners in higher classes who have already developed the bias and think it is a subject for gifted learners.

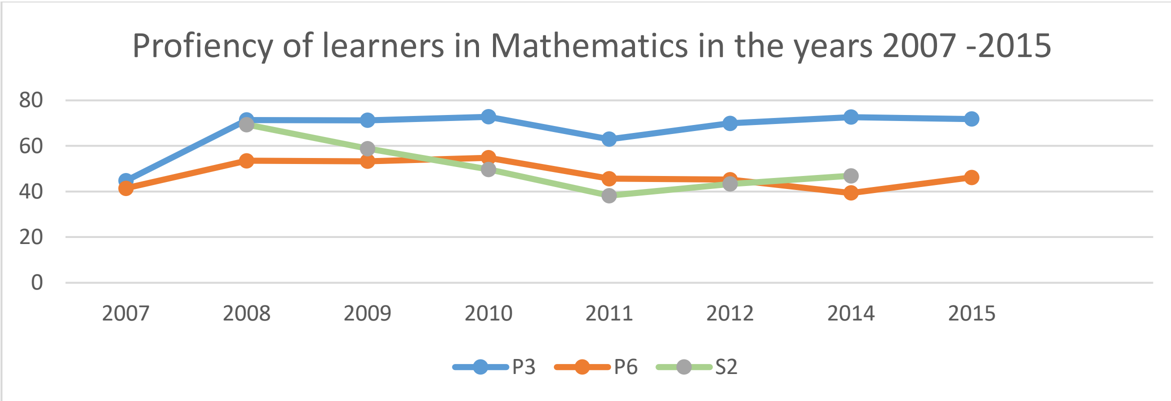



*Figure 10: Percentage proficiency in mathematics over 6 year in P3, P6 and S2*

In addition to learners' contributions, some teachers openly confess that the subject was difficult during their time and continues to be difficult. Those who teach it do so in abstract terms. In the end, some learners are not able to appreciate and later alone acquire the necessary skills in mathematics as expected. By the time the learners go through the lower secondary education cycle which lasts a period of four years, a lot of negative publicity has been done against the subject. This is supported by NAPE reports as shown in Figure 1. The percentage of learners rated proficient in mathematics between the years 2007 and 2015 in Primary 3, Primary 6 and Senior 2 during the National Assessment of Progress in Education (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, 2015), (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, 2014), (Kyagaba, Opaman, Kizito, Kennedy, & Bbosa, 2013). It shows that learner proficiency is low at secondary level compared to the primary level.

The high impact areas in mathematics that continuously influence the level of student achievement include teacher coursework, degree attainment, and certification, coupled with pedagogical training in how to teach mathematics (Hightower, et al., 2011). With appropriate pedagogy, a mathematics lesson can be highly interactive and interesting to learners when taught with the appropriate resources. This has a positive effect on the learners' retention capacity and their eventual learning achievement in the subject (Sanchez, 2002). ICT has the capacity to improve learner interactivity and leve of engagement for better learning achievement.

To address the challenges of low levels of learner achievement in mathematics, a project was initiated by National Curriculum Development Center in collaboration with MTN Foundation to extend good teaching practices of the subject to learners with the help of ICT. The project aimed at developing digital learning materials locally to support the pedagogical aspects of teaching mathematics in schools for improved learner achievement.

**The problem**

Mathematics is a practical subject which requires practical approaches to teaching for a better understanding and application of the skills acquired. This can be achieved by preparing learner-centered learning activities that engage the learner actively. Preparation of these activities requires a lot of time on the side of the teacher if they are to be engaging and interesting to the learner.

Partners in education in Uganda have some interventions to use digital educational materials for teaching and learning. These met resistance from users because of not being aligned to the national curriculum. At times they were criticised for presenting presented high pitched content to learners.

With this background, NCDC with support from MTN Foundation partnered to digitise or customise digital content in mathematics based on the senior one curriculum that uses ICT as a tool for learning.

**General objective**

The general objective of this project was improving learner outcomes in mathematics at senior one through interactive, eLearning content.

**Specific objectives**

The Objectives of the trial exercise we to:

1. determine the appropriateness S4F digital material from the teachers and learners perspectives,
2. determine how the use of S4F digital material influenced the teaching and learning of mathematics,

**Methodology**

**How the digital materials were developed**

The task to develop digital materials came at a time when staff at the National Curriculum Development Centre (NCDC) of Uganda did not have specialised training in development of digital materials for learning. All there was were two personnel trained in ICT skills and pedagogy for teaching the subject.

The project started by forming a project leadership team. This team carried out internet research for a user-friendly authoring tool (software) for creating interactive eLearning content. The criteria for deciding which authoring tool to use depending on whether the tool could be used by teachers who did not have a background in programming. Two authoring tools of Adobe Captivate and Articulate Storyline were chosen for implementing the project.

The content authoring tools were purchased and a project lead team took time to study them and how they could be used to create eLearning content. A lot of learning on how to use the tools took place with support from internet videos. Through these videos, the team was able to learn how to create simulations, interactions, quizzes with all sorts of questions, upload images and text content.

The project lead team had some members with background training in mathematics which was the subject of focus for the project. In order for them to be useful on the project, there was a need to bring onboard people with expertise in the subject to create learning activities for digitisation. The project leadership team, therefore, developed guidelines for creating a lesson storyboard. Storyboarding was new to all team members but with time the team started appreciating the need to think of the actions of the learner while using the digital material and document them. These later became very helpful at the time of developing the eLearning lesson activities for creating user interactions.

With the help of guidelines for developing storyboards, a panel of teachers was formed. These were practising mathematics teachers. The panel was oriented on how to prepare a storyboard for digitisation using the guidelines developed by the leadership team. It was a challenging task because the teachers were used to teacher-centred approaches and yet digital materials were learner-centred. The learners were expected to interact with the materials and learn on their own or with minimal support from the teacher/instructor. Benchmarking on already developed eLearning materials was very helpful.

The entire digitisation process is summarised in Figure 2 below.

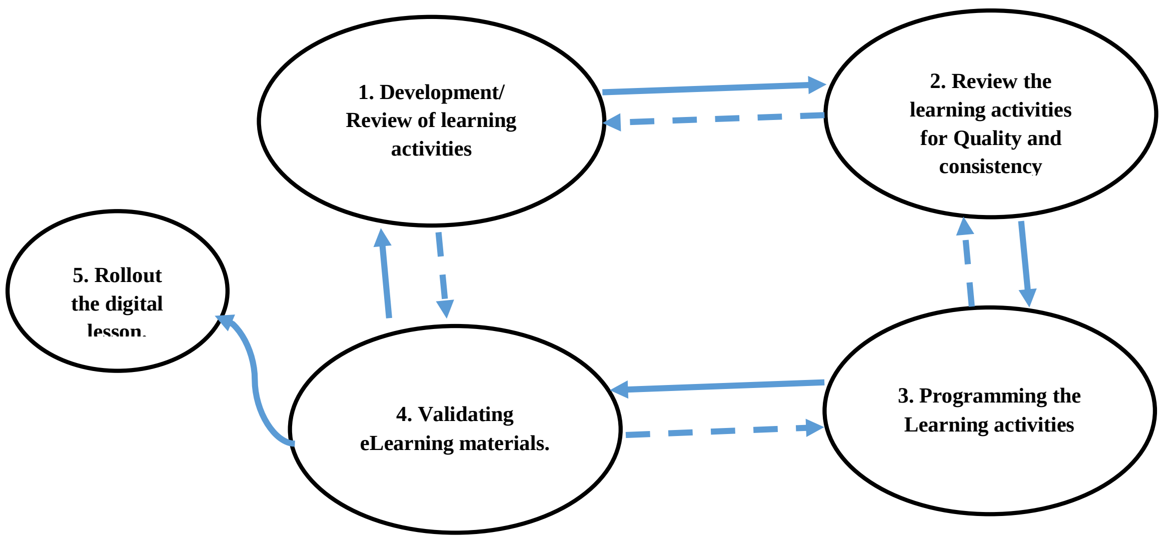



*Figure 11: The stages of the digitisation process*

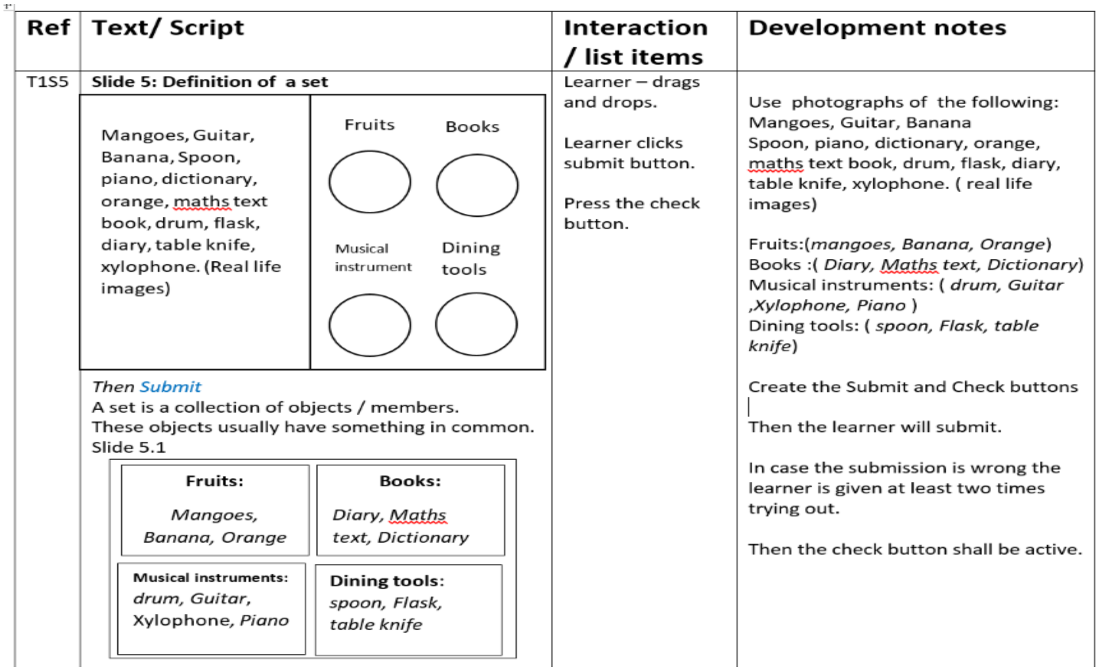
The process of developing the eLearning materials followed the following order;

1. Developing the Learning activities
2. Review of leaning activities for quality and consistency
3. Programming / digitising the learning activities
4. Validating the eLearning material

5. Rollout of the digital material

**Developing the leanring activities**

This process was carried out by mainly teachers qualified to teach the subject. With guidance from the syllabus, the teachers identified the appropriate learning activities to be digitised to support learning. These were to be as close to the local environment as possible. The teachers were charged to make the learning activities engaging, encouraging reflection on what has been learnt and gave learners control of their learning process.



| Ref | Text/ Script | Interaction / list items | Development notes |
|---|---|---|---|
| T1S5 | **Slide 5: Definition of a set**<br>Mangoes, Guitar, Banana, Spoon, piano, dictionary, orange, maths text book, drum, flask, diary, table knife, xylophone. (Real life images)<br>Fruits / Books / Musical instrument / Dining tools<br>*Then Submit*<br>A set is a collection of objects / members.<br>These objects usually have something in common.<br>Slide 5.1<br>**Fruits:** *Mangoes, Banana, Orange*<br>**Books:** *Diary, Maths text, Dictionary*<br>**Musical instruments:** *drum, Guitar,* Xylophone, *Piano*<br>**Dining tools:** *spoon, Flask, table knife* | Learner – drags and drops.<br>Learner clicks submit button.<br>Press the check button. | Use photographs of the following: Mangoes, Guitar, Banana Spoon, piano, dictionary, orange, maths text book, drum, flask, diary, table knife, xylophone. ( real life images)<br>Fruits:(*mangoes, Banana, Orange*)<br>Books :( *Diary, Maths text, Dictionary*)<br>Musical instruments: ( *drum, Guitar ,Xylophone, Piano* )<br>Dining tools: ( *spoon, Flask, table knife*)<br>Create the Submit and Check buttons<br>Then the learner will submit.<br>In case the submission is wrong the learner is given at least two times trying out.<br>Then the check button shall be active. |

*Figure 12: A screen shot showing a section of a sample storyboard*

The storyboard had a number of sections. Some of the key sections were

- the text meant to appear on the screen when one is using the content,
- the image to support the text,
- text that should be recorded as audio and will be played in the background
- an indication of what the learner will be doing while on a given page to give the programmer a sense of the interaction to be developed.

**Review of leaning activities for quality and consistency**

This session was led by what was referred to as the control group by the project leadership team. The control group was mainly made up of teachers who were biased against the subject. Majority of them did not like the subject because of how it was taught. Their major task was to critique the learning activites on the storyboard to make sure that the entire storyboard made sense to a person who did not know mathematics since the end users were learners who did not know the subject and needed to learn it. The approaches used had to appeal to this group of people in order to minimise on the monotony and boredom to students at a later stage.

**Programming the learning activities**

After critiquing the learning activities on the storyboard, it was passed on to a programmer to convert it into a digital lesson. Although this process involved mainly those who had learnt how to use the authoring tool for creating digital lessons, teachers also participated by giving additional explanation to the programmer. It is at this point that the eLearning activities were created.

**Validating the eLearning material**

The digital learning materials developed were subjected to a validation process to ensure their appropriateness and the ability to influence teaching and learning positively. The validation process involved first sharing the draft digital materials with subject specialists for more input and members of the control group. Once the concerns from these two groups were addressed, the digital materials were tried out in a school environment to get more input from students and practising teachers. All concerns raised were used to improve the quality and usability of digital materials.

**Rollout of the digital material**

This stage was not part of the development process. It is the last stage for the materials that passed through all the stages successfully and was considered ready for use by the target learners.

It is important to note that at each of the stages, the output had an option to be taken a step back if it was considred not appropriate. This is because, quality managemtn was embaded at each of the stages in order for the learning activity to progress from one stage to the next.

**Findings**

This part of the report presents the findings of the trial exercise that were obtained after analysing the data. The findings discussed are from the data that were collected through observations, feedback from the learner's questionnaire and teacher's questionnaire as well as information obtained through the focused group discussions.

**Distribution of respondents**

*Teachers who participated in the trial exercise*

24 teachers participated in the trial of S4F digital materials. 19 teachers returned the questionnaire of which 13 were male and 6 females. The teachers were drawn from both private and government-aided schools.

**Teaching experience of participating teachers**

The experience of the teachers who participated in the trial exercise cut across a wide range of experience. A majority 68.4% of the teachers had been in the teaching profession for more than 10 years. The teachers consulted, therefore, had the necessary expertise to guide on the appropriateness of the product. Figure 4 below shows the teaching experience for the teachers who participated in the trial of S4F.

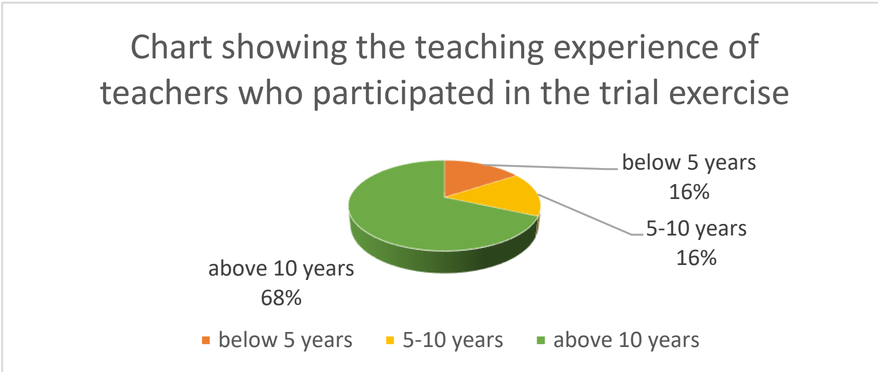



*Figure 13: Teaching experience of teachers who participated in the trial exercise.*

From this chart, all participating teachers had taught the subject long enough to understand it and make a meaningful contribution towards improving the S4F digital materials.

**Qualifications of participating teachers**

All participating teachers were qualified to teach the subject at the level the teaching materials were introduced. Figure 5 shows the highest qualification for teachers who participated in the pilot exercise. 79% of the teachers were graduates.

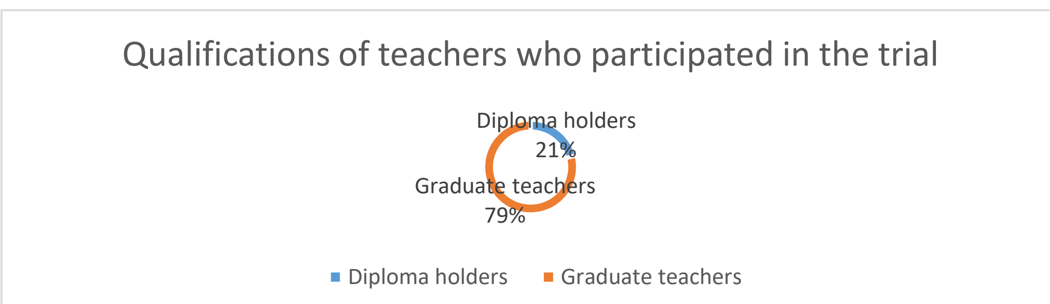



*Figure 14: A chart showing the qualifications of teachers who participated in the trial exercise*

**How S4F Digital materials were used**

During the school visits, observers noted that most schools were using the S4F digital materials in a computer laboratory on computers using NComputing technology. Teachers used the team-teaching approach to support learners use digital materials in a lesson setting. This was attributed to the lack of basic ICT skills in the majority of the learners and therefore needed assistance at intervals to progress in the lesson.

Learners using NComputing technology had challenges with getting sound from the material. This was because the technology has a downside of disabling the audio output at the client ends (terminals). In some schools, teachers improvised by providing another computer, used by the teacher or one of the learners to demonstrate and provide sound to the rest of the class. This was a great improvisation during the lesson. As the lesson progressed, the researchers noted that learners had a challenge following the audio from a central computer. This was evidenced by the decision by the majority learner to disregard the audio and work without sound since the same instructions were showing on their computer screens.

Whereas the digital materials had been designed to be used by a single learner working behind a computer or any other portable device, in most cases these learners had to share. This was mainly attributed to schools not having enough equipment for all learners to use during a lesson. During the feedback workshop, teachers acknowledged that students shared the computers in order for all of them to have access to digital materials. This is supported by the student responses where 74.6% of the learners reported to have shared computer compared to 22% who did not share while using the digital materials.

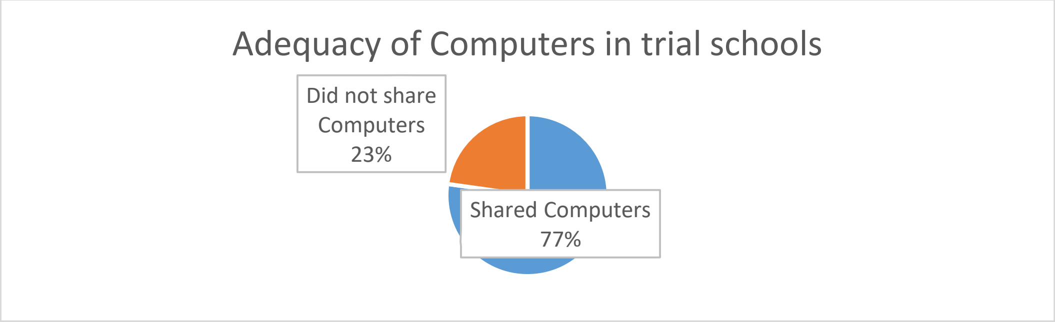



*Figure 15:Adequacy of Computers in schools*

This implies that schools do not have enough equipment to support individual use of a computer. The study findings indicate that 52% of the learners used the materials during a mathematics lesson while 37.3% used the materials outside the mathematics lesson.

**Appropriateness of S4F digital material**

One of the objectives of trying out the digital materials was to determine their appropriateness for use as teaching and learning support materials. To determine this, we considered the responses from the end users who are the teachers and students of senior one. Appropriateness goes hand in hand with the ability for the target users to pick and use the materials. This was determined by analysing the clarity of instructions, appropriate use of graphics, ease of navigation through the materials with little or no assistance and the ability to prompt and promote learning.

*Learners' response on the appropriateness of S4F digital materials.*

The appropriateness of the material was determined by considering the clearity of instructions, how graphics were used, the ability for the material to prompt learning, ease of navigation and how learning was being assessed.

*Clarity of Instructions*

The learners were able to interpret the instructions within the digital material while interacting with it. This is evidenced by the 87.0% of the learners who found all the words used in the digital materials simple and easy to understand, 86.4% who noted that the material had all the necessary information a learner needed to do the work and 82.5% who found the instructions in the materials easy to understand and follow. It is worth noting that 93.8% of the learners reported that additional instructions from the teachers were very helpful.

This implies that the instructions used in the S4F digital material were at the level of the learners' understanding and can be used for self-paced learning. Simplified instructions also made it possible for the learners to follow through the learning material with or without support from their teachers. However, additional support from the teachers on how to use the computers made it much easier for the learners to use the digital material.

*Use of graphics*

S4F digital materials used graphics (images, pictures, illustrations, charts and visuals) in all lessons. This was to make the lessons appealing but also enable the learner to relate what they learn in class with what happens in their actual environment. Feedback from learners shows that 97.2% found the graphics helpful to them in understanding the concepts in the lesson, 88.2% note that they made the lesson interesting. In addition, 59.3% of the learners reported that the images and pictures helped them relate learning to what happens in their immediate communities while 15.8% reported that the images were not related to their immediate environment. Further analysis on this showed that the images which were found not familiar to learners were in the topics of commercial and household mathematics (14.3%), Fractions and percentages (19.0%), general and angle properties (15.0%), set theory (33.3%) and statistics (11.1%).

This shows that the use of graphics and visuals adds value to a lesson. The responses above show that the graphics made the lessons more interesting and easier to follow. This can be a source of motivation for the learner to learn the subject and even excel at a later stage. The graphics elicited learners interest in the learning of the subject. Graphics that were familiar to learners enabled them not only to understand but also to relate what they learnt in class with what happens in their immediate communities. This puts students learning at the levels of analysis and evaluation on blooms taxonomy of learning, where the learner is able to draw connections among ideas and appraise them respectively. This is a high level of learner engagement which is desired for all learners. Once the graphics that were identified to be unfamiliar the  to more appropriate ones, then the images will make the lessons more interesting and enjoyable to learners.

*Ability to prompt and promote learning*

The materials encouraged learner to learner interaction and collaboration, especially when used during a lesson set up. This was through asking classmates for assistance and some questions or tasks required the learners to work in groups. This is evidenced by the 53.7% of the learners who asked classmates while using the S4F digital materials and 39.0% did not.

We noted that 53.7% of learners who interacted with classmates is highly related to the 52.0% who used the materials during the lesson set up while the 39.0% of respondents who did not ask their classmates is also highly related to 37.3% who did not use the materials during the mathematics lesson. This, therefore, means use of this material in a classroom setting develops the attributes of collaboration and teamwork.

*Navigation cross pages*

About navigation from one page to the next, the learners scored the digital material at 68.9%. This could be explained by the challenges encountered during use where learners noted that the computers they were using were very slow. The same concern was raised during school visits and in the discussion between the project team and the teachers. The 11.3% who found it not easy to move from one page to the next was contributed by the following topics; Commercial and household mathematics 21.4%, Fractions and percentages 21.4%, Graph plotting 6.7% and statistics 16.7%.

*Assessment of learning*

The digital materials gave the learners a chance to assess themselves on the content throughout the lesson. Learners liked the immediate feedback on the questions attempted and this motivated them to learn as described by this response from one of the learners *"I like this system because when you do a question, it marks you immediately".* About the type of questions set, 70.1% of the learners found the questions very simple. This is confirmed by the 62.1% who add that the questions did not require a lot of thinking compared to 25.5% who thought otherwise.  In addition, 41.8% and 49.1% note that the questions were tricky and required learners to discuss respectively. There was a strong agreement from the learners of 91.5% about the questions being aligned to the topic that was being studied. What remains to be determined is whether the questions were simple because of the alignment to the topic just covered or it was a result of the increased learner interest and motivation in the subject created by the same digital materials. This needs to be studied further.

*Teachers' response on the appropriateness of S4F digital materials.*

The teachers' response to the use of S4F digital materials was in six main areas. These are; appropriateness of the digitised content, appropriateness of the language used in the materials, the learning approaches used, appropriate use of graphics (illustrations and images), interactivity of the materials and assessment of learning. Table 1 below shows a summary of how teachers rated the S4F digital materials in each of the six areas.

| S/No | Area of concern | Disagree % | Not Sure % | Agree % |
|---|---|---|---|---|
| 1 | Content was well presented for the level | 3.8 | 4.5 | 91.7 |
| 2 | Language used was appropriate | 0.0 | 3.5 | 96.5 |
| 3 | Learning approach were clear and suitable | 5.3 | 4.4 | 90.3 |
| 4 | Appropriate Illustrations/Diagrams were used | 4.0 | 1.3 | 94.7 |
| 5 | Interactivity of the materials was clear and appropriate. | 11.7 | 7.6 | 80.7 |
| 6 | Assessment of learning objectives was well done. | 6.2 | 10.5 | 83.3 |

*Table 3: Teachers' responses on the appropriateness of S4F digital materials*

*Content in the materials*

In the area of content presentation, all the teachers (100%) who participated in the trial exercise noted that the S4F material facilitates the understanding of mathematics, present content in chronological order from what the learner already knows toward learning new concepts in the subject (known to unknown). The content was found to be linked to real-life situations which learners can easily relate with. Developing learner's mathematical skills, interest and positive attitude towards learning the subject were scored at 94.7%, while its relevance to the intended learning objectives and goals was scored at 89.5%. The lowest score came from the coverage of the syllabus objective where 63.2% of the responded felt that the material exhausted all the content that the learners needed to know while the 26.4% felt it had not.

*Language used*

All the teachers agreed that S4F digital materials used appropriate vocabulary with clear sentences and a standard language was used. This agrees with the learners who noted that the language used was simple and appropriate.

*Teaching and learning approaches*

In the area of learning approach, 100% of the teachers noted that the materials promote learners self-discovery. This was followed by having learning activities that are relevant to the content being taught/learnt, appropriate to the level of the targeted learners and facilitate learner's involvement in the learning at 97.4%. Use of this digital content was also found to provide room for teacher's further creativity and innovation where necessary.

*Use of illustrations and images*

In addition to the learning approach, teachers applauded the S4F for using illustrations and images that are relevant and familiar to the learner. This view about the material is shared by the learners as well.

*Interactivity*

About the interactivity of the materials. Teachers like their learners noted that the material was interactive. However, there were some areas which needed more attention to make it more interactive and interesting. These are navigating from one page to the next, making a provision for the user to get help/hint when needed and the working of the access control buttons. Teachers suggested the need for a slider to allow the learners to scroll back and forth where need be. They also suggested more improvements on the home page and to make it more user-friendly and improvements in the instructions to the learner.

*Assessment*

On assessment, the teachers noted that the S4F materials provide timely assessment to learners that is appropriate to the lesson objectives. It was noted that the assessment activities are aligned with the content. There was a need to increase the number of assessment activities. What was provided in the materials was rated as insufficient and not able to support progressive assessment of learners.

**Influence of S4F on the teaching and learning of Mathematics**

Another key objective of the trial exercise was to determine the ability to improve the achievement of learning objectives through use of digital learning materials. In general, it was observed that use of these digital materials facilitated learner to learner interaction learning approaches, increased level of interaction between the learner and the teacher and motivated learners to learn the subject.

*Ability to support individual and group learning*

Use of digital materials had an effect on learners attention span during the lesson. In our lesson observations, learners were seen actively engaged and motivated to learn the subject content. Even where teacher involvement was low, the learners have the zeal to move on without teacher supervision and involvement. This is confirmed by their responses where 94.9% of the learners found lessons with digital materials interesting and fun to work with. The learners expressed their strong liking for the S4F digital materials and desire to have more of the kind. This view was shared by 92.6% of the learner respondents compared to 3.4% who disagreed with this it and the 4.0% that was undecided. This is also supported by the result on statement number 15 which shows that 90.9% of the learners found the materials nice and interesting to use.

As noted earlier, the materials encouraged learners to learner-to-learner interaction and collaboration. Through this interaction, it is believed that learners would unconsciously develop the skills of communication, collaboration and teamwork that are part of the much needed 21st century skills in addition to mathematical skills. These would otherwise not be realised if each student concentrated on their personal academic work.

**Influence on how mathematics is taught**

The study sought to know whether the introduction of S4F digital teaching materials had an influence on the way the subject is taught in the classroom. The table below presents a summary of how S4F influenced the teaching of mathematics for the learner's perspective.

| S/No | Learner response statement | Frequency | Percent |
|---|---|---|---|
| 1 | material was enjoyable/interesting | 127 | 71.8 |
| 2 | easy to understand and use | 121 | 68.4 |
| 3 | use of pictures and more of real life situations | 109 | 61.6 |
| 4 | was boring because of a few computers | 76 | 42.9 |
| 5 | It encourages self-learning | 73 | 41.2 |
| 6 | The lesson gives chance to try again | 61 | 34.5 |
| 7 | It was fun because of computers | 55 | 31.1 |
| 8 | much time is taken when learning as compared to other lessons | 49 | 27.7 |
| 9 | All work was on the computer, less use of paper | 49 | 27.7 |
| 10 | Many examples were given | 49 | 27.7 |
| 11 | There were self-marking exercises | 46 | 26.0 |
| 12 | The material is understandable than the teacher | 40 | 22.6 |
| 13 | students were extremely attentive | 40 | 22.6 |
| 14 | Calculation are at a high speed | 37 | 20.9 |
| 15 | Mistakes are not corrected in the material | 31 | 17.5 |
| 16 | I felt good when my answer were marked right | 31 | 17.5 |
| 17 | Material has tricky Questions | 31 | 17.5 |
| 18 | does not explain like how the teachers explain | 28 | 15.8 |
| 19 | required us to use our knowledge of computers | 22 | 12.4 |
| 20 | one can easily get the answer | 22 | 12.4 |
| 21 | the lesson was boring because I knew some questions | 19 | 10.7 |

| | | | |
|---|---|---|---|
| 22 | the lesson was boring compared to the maths teacher | 19 | 10.7 |
| 23 | The lesson was detailed | 19 | 10.7 |
| 24 | we used a projector | 19 | 10.7 |
| 25 | Material gives more chance to try again. | 19 | 10.7 |
| 26 | the lesson does not require a lot of discussion | 19 | 10.7 |
| 27 | computers construct angles on their own, not me | 16 | 9.0 |
| 28 | saves time | 16 | 9.0 |
| 29 | the material doesn't require a lot of thinking | 16 | 9.0 |
| 30 | The material gave me answers | 16 | 9.0 |
| 31 | The material gives a good explanation | 16 | 9.0 |
| 32 | The lesson required a lot of thinking | 16 | 9.0 |

*Table 4: Influence of S4F digital materials to the teaching of Mathematics*

Majority of the learners (71.8%) noted that lessons, where learners used S4F digital materials, were enjoyable/interesting, easy to understand and could easily be linked to real-life situation because they used related pictures and images. This also implies that the traditional approach to teaching the subject is abstract for the learners. This challenge can be overcome with use of real-life objects during the lesson to enable the learners to comprehend, synthesise and related the knowledge learnt to real-life situations.

The teaching approaches used depended on whether the school was resourced with ICT equipment or not. In schools that were well resourced, teachers naturally used a team-teaching approach without any challenges. Where a school was not well resourced, a single teacher dominated the lesson activities to the extent of trying to do everything for the learners. In some, the information was displayed to learners with the help of a projector as the teacher or one of the students demonstrated how to interact with the resource. This is evidenced by 42.9% who agreed that sharing computers made the lessons boring to some learners.

Use of S4F materials for teaching helped learners engage with their teachers in a discussion about the subject content. The interaction was mainly on interpreting the instructions in order to do the learning activities as well as operating the ICT equipment used for learning. This in a way promoted teacher-to-learner and learner-to-learner interactions throughout the lesson. This allowed learners to participate more actively in the learning process.

Opening up learner to learner interactions had an effect on the way classes have been conducted. Where learners were expected to be silent and working as individuals, group activities and discussions became more acceptable. This turned the quiet classroom to an interactive and active class.

The table below shows learner responses about the lesson taught with S4F materials. In general, use of S4F materials has a positive effect on the lesson than the negative as shown by the responses and their corresponding frequencies in the table below.

## Conclusion

The methodology for developing digital learning materials is not rigid. One can customise it as they wish and still produce relevant learner-centred digital learning materials that are interactive and able to stimulate learning.

This intervention has shown that teachers who never attended computer programming lessons have the ability to develop digital learning materials to support their teaching. They do not have to undergo computer programming lessons before they are qualified to develop a digital lesson. They only need the right content authoring tools to get started. Digital education support materials do not have to be highly animated to be effective. They are more effective is they can appeal to the learner by relating learning to what happens in the learner's immediate environment.

The control group had a big role to play towards making the material userfriendly. They question the status quo and assist the subject experts to tone down the explanation to the level of learners.

## Recommendations

Following the development and trial of S4F digital materials, the following recommendations were made for purposes of improving the use of digital materials in schools and for private reading/learning

At the school level, where computer laboratories have been established, they should be opened up to learners for research, content sharing and teaching of all subjects on the curriculum menu.

Governments should encourage and empower in-service teachers to develop digital learning materials locally. This way all schools will have sufficient digital materials that are tailored to the needs of a specified group of learners and their curriculum.  This is very possible with the use of GUI oriented authoring software

In partnership with teacher-training institutions, Governments and other education partners should conduct specific and intensive training for teachers to acquire Technological Pedagogical and Content Knowledge (TPACK) of using digital content to enhance students' learning outcomes. Acquisition of skills in the development of digital content should be part of the teacher training course.

Educationists should emphasise the use of items from their immediate local environment for graphics and examples in the production of digital materials. This facilitates learning from known to unknown.

Procurement of ICT devices for use in schools by ministries and school management should always ensure that they have support for audio and visual elements. Some modifications made on these devices disable some of these elements making them not suitable for use during a teaching and learning process that involves digital materials.

Curriculum centres across Africa should make every effort to create repositories of locally developed content to facilitate content sharing and peer support among teachers. This will lead to improved curriculum delivery across African countries.

The project should be scaled up to more schools and more subjects to support learning across the country.

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**Article 35**

# Effects of Open Educational Resources (OERS) video explainers/graphic motion in a blended physics classroom

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**Abstract**

Animated materials have been used to enhance learning process for a long time. There are various categories of animations; Traditional Animator, 2D Animations, 3D Animation, Stop Motion and Graphic Motion. The research project made use of stratified purposive sampling was used. Ten students were selected from chosen school. Five students from each school were put in focus group while five students were put in control groups. The inertia topic was taught to both groups, where the focus group classroom was blended with online OERS. Control groups were taught using the traditional lecture method. A theory and a practical test were later administered at the end. The main objectives were: To establish the effects of using of video explainers (graphic motion) animations on performance in skills acquisition in physics and to determine performance percentage of use of motion graphic animations in content delivery of physics curriculum in a timely way compared to a controlled situation. The research project made use of stratified purposive sampling. Ten students were selected from 4 school. Five students from each school were set in focus group while five students were set in control groups. Inertia topic was taught to both groups, where the focus group classroom was blended with online OERS. Control groups were taught using the traditional lecture method. A theory and a practical test were later administered at the end. The result showed that the focus outperformed the control groups in all aspects. The study recommends that Information Communication and Technology should have institutional framework for efficient integration of ICT in the entire education sector.

**Keywords:** *Animations, Graphic Motion, Blended Classroom, video explainers, content delivery, Educational Model*, *Mimio*

**Abbreviation:** *ADDIE-Analysis, Design, Development, Implementation, and Evaluation, EFA-Education for all, ICT-Information communication technology, KICD -Kenya Institute of Curriculum Development, KLB- Kenya Literature Bureau, MDGs-Millennium Development Goals, OERS-Effects of Open Educational Resources, TSC-Teachers Service Commission*

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## Introduction

There has been a challenge of improving physics performance in Kenya public school. The performance has been attributed to lack of teaching apparatus and relevant resources in school. Most schools have not integrated ICT to a level that helps learners and teachers access resources adequately. Most student lack proper grasp of physics concepts, especially when lectured in a normal classroom situation. In addition, less visual video and graphics may have contributed to poor grades in the subject. It is in light with this that graphical motion animations were identified as tool that can be used to eradicate this problem. I have been a science teacher (Physics) in different schools in Kenya, for the last 15 years. There have been a lot of challenges and insights throughout my career in teaching and learning of science subjects. These challenges include but not limited to scarce resources, time for preparation and human resources (teachers and laboratory technicians). The performance in physics has been underperformed partly because of the issues that have been stated here. Teachers seek rare resources and spend a lot of time in preparing for demonstrations and practical's. Hence the worthy idea to research and do a project that could collect animated materials for physics related activities for use in various sessions of learning, was conceived. Tuition fees will be minimized as most of the physics demonstrations / activities need not to be repeated. They can be recorded or already recorded for re-winded later, hence saving more time and resources. A publication my McGraw – Hill education gives an ideal model for ICT related practical where "the teacher brainstorms the background science ideas behind the experimental work using interactive whiteboard or mimio and work is saved as a web page or put into a shared file from lab via radio link to the network and for use at later hours" this is a good idea but it has to be taken further by organizing work as per topics in a curriculum format. Hence, generalization that results can be achieved due to use of the said model is reduced. Improvement on animation that is well organized can be of greater help. Lack of science laboratories where the timetable could not fit all sets of practical sessions in a school hinders demonstrations and practical from providing effective learning process. If ICT tools such as mobile phones and internet are put in place, then the learning process can take place any time anywhere.

A teacher needs not to be present always for the practice of practical skills, this removes the aspect of over reliance of a teacher. Dangerous and expensive experiments can be repeated severally without much health side effects. This cuts of cost of health issues and school finances. Other countries across the world have been in every effort to intergraded education with ICT. According to information paper No. 22 – April 2014 titled ICT in Education in Asia – ICT in education has a multiplier effect through the education system where it enhances new set of skills and reaching students who are poor or with no access. At international level – 40 years ago – a policy for integrating ICT for development was formulated in Millennium Development Goals) MDGs). This was further incorporated in Education for all. In EFA ICT has been indicated as pivot in achieving access, eliminating exclusion and improving quality. In 2003 and 2005 – the world summit on the information society (WSIS) governments resolved foster and inclusive information society. Asia countries were in electronic readiness by 2012 September. Most countries had infrastructure to support ICT, computers, computer laboratories, ICT support services and internet. Although they were at different stages of ICT education, they all focused on ICT integration. Study of 174 ICT supported classroom in 128 countries, there was direct connection between the innovation and national policies that promoted the use of ICT (Jones, 2003). Infact most of the countries has national policies on ICT education in 21st century, save for Inida since it is done at federal level. The bottom line is that using animation can help the government to fast track it needs to offer free secondary school where the cost of buying books and other perishable items is minimized since repetition can be done online or through content stored in secondary storage of computers.

**General Objective**

The general objective was to determine the impact of using graphic motion (Video explainers) in learning and teaching of physics in Kenya public secondary school.

**Specific objectives**

The specific objectives of the research were as outlined below:

i. To establish the effects of using video explainers (graphic motion) animations on performance in skills acquisition in physics.
ii. To determine performance percentage of use of motion graphic animations in content delivery of physics curriculum in a timely way compared to a controlled situation.

**Literature Review**

**Meaning of Animation**

A variety of explanations and definitions animation from one dictionary to another and from scholar to another have been advanced. Collins Dictionary gives definition of animation as manipulation of different images that are generated by electronic device to create more images. However, the definitions of animation keep changing from time to time.

According to Omor (2015), one of the main arguments that dismisses distinguishing animations is that because digital moving images are generated from information the images are dissociated from the index of their photographic record and their real time. Animation is any form of images, text or drawing with an illusion of motion. Hence, the research took animated videos as motion graphics.

**Categorization of Animations**

Animations can be classified into five major categories using the style that accompanies them.

**Traditional Animator and 2D**

This category of animation uses methods that are not digitally aligned. Physical tools, materials, and activities are used instead. Examples of animations that fall in this category are traditional 2D cell and stop motion

**3D Animation**

It makes use of computer hardware and software. Good software is Cheetah3D and blender. Computer graphics generate the images for animation where used in series.

**Stop Motion**

In stop motion, individual still images are captured from camera for animation. Still objects are brought to life when screened. It offers more creativity in video production.

**Graphic Motion/video explainer**

Graphic motion makes use of digital footage or animation that seems to move or rotate. Audio is combined to the animation or digital footage to make a multimedia projects**.**

**Graphic Motion in Classroom**

Specific benefits of graphic motion compared to other types include; they do not lose some real life information required for learning. Aligning them with curriculum is easy they do not require expertise in programming technology in order to cater for different level of students.

They do depict actuality and facts like. The other types of animations are an artistic recreation.

**Empirical Review**

**Performance**

Trevisan, et al (2017) compared two groups of learning. One group used video of traditional lecturer while the other group used animation as the learning material. The topic was follicular dynamics in physiology. An immediate one off test was used as the evaluation instruments. The results in general showed that those who used animation got significantly higher marks.

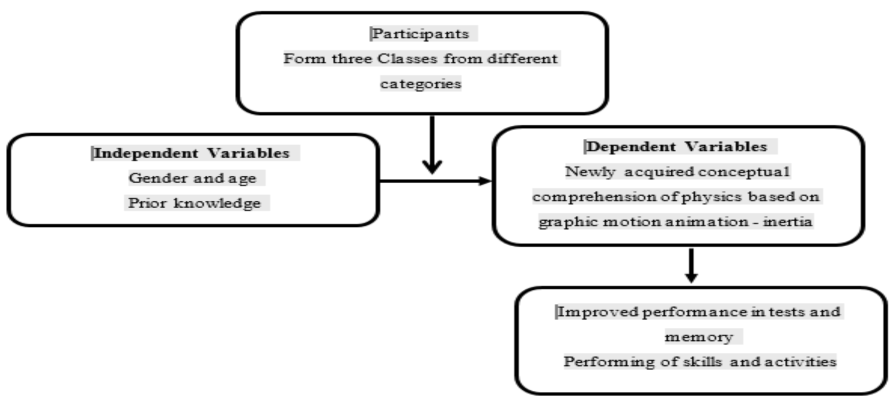
## Saving Time

A graphic animation accelerates the learning process since there is change in behavior of the learner towards better acquisition of knowledge and skills. According to task affected, them by Rosemary Deaney et al, (2003) it was noted 'this theme concerns the contribution of ICT use to effecting tasks encountered within academic work. Pupil in all year groups and schools reported how use of ICT tools enabled them to carry out such tasks with ease, quickly and to a high standard; therefore, in applying the right pedagogy, motion graphic animation goes along way into easement and saving time.

In a case study by Sabanci A., (2014) "the effect of ICT usage on the classroom management" he concludes, "the findings also indicated that when all kinds of teaching materials used with and in ICT are designed to meet student's interests and needs, undesirable behavior are likely to decrease and teachers can focus on the students learning better. On the other hand, teachers complained of the central character of the education system about planning the content and they believe.

Since graphic motion is not an isolated component of ICT, its application involves devices that entrenches fast delivery of learning content.

Figure1: Conceptual Framework




## Methodology

## Educational Model

The project made use of ADDIE Model. ADDIE stands for: -Analysis, Design, Development, Implementation, and Evaluation. The model has been in use for a while and it seems like the other models borrow heavily from it.

Kurt's, (2017) notes practitioners over the years have made several revisions in the stages of the original hierarchical version. This has made the model more interactive and dynamic. It was in the mid-1980s that the version similar to the current version appeared. Today, the influence of the ADDIE method can be seen on most ID models being used "Most of the ICT related learning considers this models steps for any effective learning outcome. It helps the trainers and teachers to plan, have required materials well sorted and delivery strategy aligned to the intended outcome.

In the article by Raba, et al (2016), applying a structured instructional design model for creating professional development program for physicians is fruitful, relevant experience in primary health care. This reason cut across all areas of ICT integrated learning. It is for this reason; we found the model relevant to us course. Michael, et al (2003) adds by writing, "what is emerging in the recent literature is a tendency to accept the ADDIE term as an umbrella term, and then to go on to elaborate more fully flashed-out models and narrative descriptions.

The following were the issues and tasks done for each step in the research:

*Analysis*

The audience was identified as a form 3 physics class. The intended outcome was for the students using graphic animated students to improve both in grade performance and in skills attainment. The constraint identified was lack of materials in teaching the topics can be eased by the animated items.

*Design*

The scheme and lesson plans were prepared. Text notes for the topic were made. Since there was, need to get the right learning outcome such as cognitive, effective and psychomotor behavior, relevant motion graphics were sourced.

*Development*

The content was assembled both in print and on softcopy. The links for the videos shared to the teachers and learners.

*Implementation*

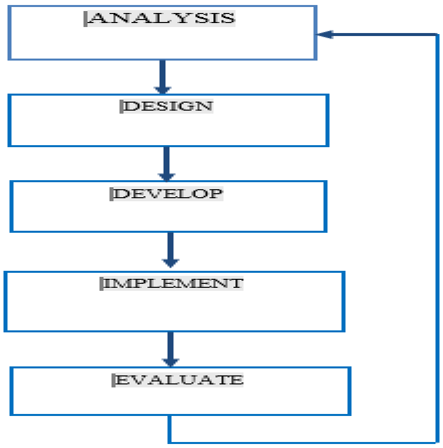
The learners and teachers were guided on the procedure and activities that were to be done. Teachers and learners were registered for the course. The use of computers/laptops and links was smoothly done.

*Evaluation*

According to Amanda, et al (2016)" while the authors and their colleagues see the ADDIE framework to facilitate student engagement in a credit-bearing course, this structure might be used by librarians in a variety of instructional situations. This process can be scaled down to fit smaller or more discrete instructional needs, because a systematic designing process that in corporate feedback is essential to designing meaningful learning opportunities.

The following are some features that make ADDIE a better option compared to other models: It has a good quality design, has clear learning objectives, it allows for a good structured content, it offers a better feature integrated media, it gives relevant students activities, its assessment tied strongly to desired learning outcomes.

Figure 2: The ADDIE flow chart




**Data Collection**

The research sought to get data intended to respond to the research questions. The main areas were:

Student performance as a result of using graphic animation as compared to situation where we have other types of animation or none.

The acquisition of the required skills-on completion time of the given task. Time factor was crucial.

Retrieving Learning graphic/videos related to Inertia topic from youtubes channels

**Research Design**

The project used experimental design where learners were not pre tested. There was control group and focus group for each school. According to Bhat A, (2019) 'True experimental research is the most accurate form of experimental research design as it relies on statistical analysis to prove or disprove a hypothesis. It is the only type of Experimental Design that can establish a cause-effect relationship within a group/s'

By using this design, the research was destined to achieve its achievement, as most accurate data was to come from the scores and activities done by the learners.

**Sample Population and Frame**

Forty (40) students were involved in the project from four schools. The first task was to identify schools for the research project. The research project used four schools cutting across different categories as follows:

National boarding Schools-Here the school that was selected was Starehe Girls'

County boy's boarding Schools-Aquinas high school in Makadara, Nairobi was identified for the research project.

County girls boarding schools-The county school was Embakasi Girls' secondary for the project.

Day mixed school-Kahawa Garrison was selected as an ideal school to be part of the project.

In each school – ten students in form 3 were selected for the research project in liaison with host teacher as explained earlier. Five students for the focus group while the other five students for the control group.

**Sampling Students for the Research Project**

The project applied stratified purposive sampling. It was done by grouping learners to groups of twenty. The students were then given numbers from one to twenty. These groups were again put into sub groups of five students. It is from this order the learners in order numbers were taken to select ten students. The odd numbers students were then assigned X and Y in alternative way. Learners assigned X were the focus group and those assigned Y were put under control group. This was done across all the schools involved in the research project.

Table 1: Schools studied

| **School** | **Letter Assigned** |
|---|---|
| Embakasi Girls | A |
| Aquinas High School | B |
| Kahawa Garission | C |
| Starehe Girls | D |

According to Ashley, (2018) A stratified sample is one that ensures that subgroups (strata) of a given population are each adequately represented within the whole population of a research study. For example, one might divide a sample of adults into subgroups by age, like 18-29, 30-39, 40-49, 50-59, and 60 and above. To stratify this sample, the researcher would then randomly select proportional amounts of people from each age group. This is an effective sampling technique for studying how a trend or issue might differ across subgroups."

The learners were divided into groups of twenty, in respect to their performance as earlier mentioned. In each group of 20 students, they were again divided into four groups of five and sequentially arranged.

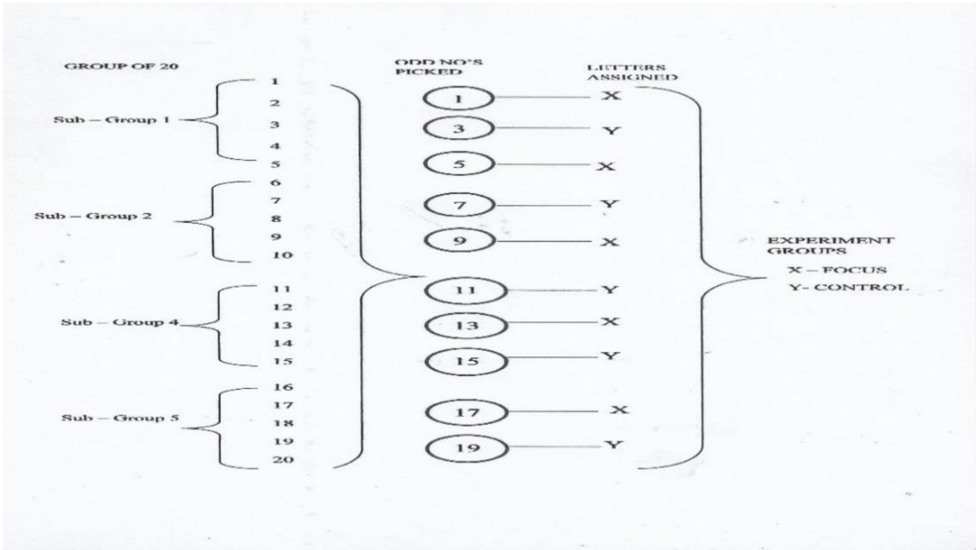



**Figure 3: Group Selection Criteria**

**Graphic Motion Videos Used**

These were the videos / You Tube links used and shared/downloaded from Open Education Resources (OERs) are listed below. There was no editing, for the videos.

- https://www.youtuvbe.com/watch?v=6gzCeXDhUAA
- https://www.youtuvbe.com/watch?v=6gzCeXDhUAA
- https://www.youtuvbe.com/watch?v=yAKEDEgwFC4
- https://www.youtuvbe.com/watch?v=erghLWXDScl
- https://www.youtuvbe.com/watch?v=NYVMlml0BPQ
- https://www.youtuvbe.com/watch?v=NYVMlml0BPQ

Video Screenshots Samples

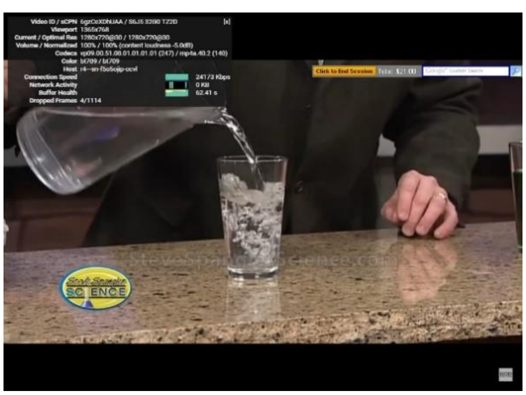


Figure 4: Egg experiment

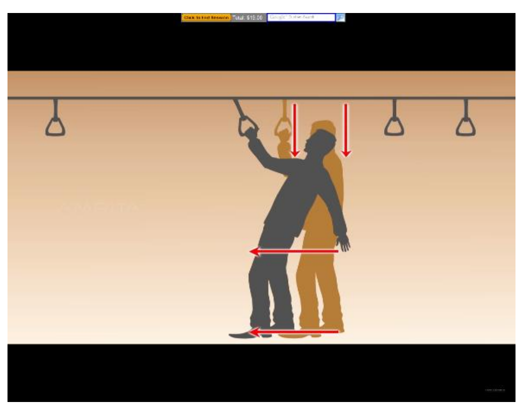


Figure 5: Motion Inertia

### Project Experiment Implementation

### Control Groups

For each school, the co-operating teacher taught Inertia Sub-topic using his normal classroom methods. They did this by use of the materials form the course textbooks, in this case KLB Book Three. Teachers were free to do improvised demonstrations for Inertia concepts. Revision materials and assignments were given as norm.

### Focus Groups

This category of group was exposed to the selected videos that demonstrated Inertia in graphic motion. The content was similar with that of control groups but demonstrations were done by playing the selected videos.

### Assessments

At the end of two weeks, the two categories of groups were assessed. The tests dates for each school were different because of their different schools' programmes and availability of the research team. Both control and focus groups did a theory test and then practical test activities latter on.

### Data Collected

Students' scores and duration for the completion of planned activities were key data that the research needed for the objectives. The scores of students were recorded and video capturing certain activities on inertia where time of completion was recorded.

The researcher also noted the number of activities well done, according to his expertise judgment and in consultation of the other teachers.

The videos captured were analyzed and the number of well-done activities recorded.

Figure 6: Screenshots of Students in action

## Data Analysis

### Performance

Spreadsheet excel software was used for data analysis. The mean score, deviations, and variance worked up for both focus and control group as a percentage.

**Table 2:** Mean Marks Comparison

| Focus Group | | Control Group | |
|---|---|---|---|
| Student | % | Student | % |
| 1 | 70 | 1 | 60 |
| 2 | 20 | 2 | 60 |
| 3 | 70 | 3 | 50 |
| 4 | 90 | 4 | 40 |
| 5 | 90 | 5 | 20 |
| 6 | 90 | 6 | 60 |
| 7 | 90 | 7 | 70 |
| 8 | 100 | 8 | 80 |
| 9 | 70 | 9 | 70 |
| 10 | 100 | 10 | 50 |
| 11 | 60 | 11 | 5 |
| 12 | 50 | 12 | 50 |
| 13 | 80 | 13 | 5 |
| 14 | 90 | 14 | 0 |
| 15 | 80 | 15 | 5 |
| 16 | 80 | 16 | 30 |
| 17 | 80 | 17 | 20 |
| 18 | 100 | 18 | 60 |
| 19 | 70 | 19 | 70 |
| 20 | 70 | 20 | 40 |
| Mean | 77.5 | | 42.25 |

**Table 3:** Mean Marks Comparison

| | Focus Group | | Control Group | |
|---|---|---|---|---|
| Students | Marks (%) | Expected | Marks (5) | Expected |
| 1 | 70 | 77.5 | 60 | 42.25 |
| 2 | 20 | 77.5 | 60 | 42.25 |
| 3 | 70 | 77.5 | 50 | 42.25 |
| 4 | 90 | 77.5 | 40 | 42.25 |
| 5 | 90 | 77.5 | 20 | 42.25 |
| 6 | 90 | 77.5 | 60 | 42.25 |
| 7 | 90 | 77.5 | 70 | 42.25 |
| 8 | 100 | 77.5 | 80 | 42.25 |
| 9 | 70 | 77.5 | 70 | 42.25 |
| 10 | 100 | 77.5 | 50 | 42.25 |
| 11 | 60 | 77.5 | 5 | 42.25 |
| 12 | 50 | 77.5 | 50 | 42.25 |
| 13 | 80 | 77.5 | 5 | 42.25 |
| 14 | 90 | 77.5 | 0 | 42.25 |
| 15 | 80 | 77.5 | 5 | 42.25 |
| 16 | 80 | 77.5 | 30 | 42.25 |
| 17 | 80 | 77.5 | 20 | 42.25 |
| 18 | 100 | 77.5 | 60 | 42.25 |
| 19 | 70 | 77.5 | 70 | 42.25 |
| 20 | 70 | 77.5 | 40 | 42.25 |
| Mean | 77.5 | | 42.25 | |
| Sdvt | 19.15999121 | | 25.41627121 | |
| Var | 367.1052632 | | 645.9868421 | |

One of the key aspects that the project sought to find out is the results performance between control group and focus group. Consequently, it necessitated an evaluation quiz that was marked for all forty students. Twenty of them were in control groups and the other twenty in the focus group. The results obtained were as shown in the above table and recorded as percentage for each student.

### Time Data Analysis

Completion period of performing assigned tasks/activities was crucial part of the research project. There was video recording of the control and focus group performing tasks assigned to them and time was recorded from the videos clips.

The mean was calculated and the difference in time of the two groups was 203 seconds. To simplify and relate to our research focus, the time difference was recorded as the time saved which was auto calculated for a year. Taking a lesson to be 40 minutes, the total number of lessons saved was auto calculated as shown.

**Table 4**: Analysis for time (seconds) saved

| School | Focus Group | Control Group | Dev(In 1 Lesson) | Time Saved Weekly | Time Saved per Term | Time Saved Yearly | Minutes Saved Yearly | Lessons Saved Yearly |
|---|---|---|---|---|---|---|---|---|
| A | 170 | 353 | 183 | 915 | 10065 | 30195 | 503 | 13 |
| B | 59 | 180 | 121 | 605 | 6655 | 19965 | 333 | 8 |
| C | 78 | 148 | 70 | 350 | 3850 | 11550 | 193 | 5 |
| D | 56 | 259 | 203 | 1015 | 11165 | 33495 | 558 | 14 |
| | | | | | | **Mean** | 397 | 10 |

**Task Completion Analysis**

It was again, from the four tasks given to the learner's that the teachers and the researcher assessed the number of tasks well performed and completed for each group for the four schools.

**Table 5**: Accomplished Tasks

| | Focus Group | Control Group | | | |
|---|---|---|---|---|---|
| **School** | **Activities Done** | **Activities Done** | **Deviation** | **Weekly** | **Yearly** |
| A | 4 | 2 | 2 | 10 | 330 |
| B | 3 | 2 | 1 | 5 | 165 |
| C | 4 | 3 | 1 | 5 | 165 |
| D | 4 | 2 | 2 | 10 | 330 |
| | | **Extra** | **15** | **75** | **248** |

**Conclusion**

The challenge of learning and teaching physics in Kenya Secondary schools cannot be understated. Lack of resources and the right pedagogical skills hinder good learning process. This trend is consistent and require paradigm shift on the way learning materials are provided to the learner. The acquisition of knowledge is pegged on how we incorporated all these components of learning.

The research looked at different questions. First, popularity of graphic motions in teaching sciences. Through literature review the most commonly used kind of animation that is used in most teaching, not only in physics but in most of science oriented subjects is graphic motion. As evidenced by the scenarios given in literature review teachers use video, YouTube and animated text in their teaching.

Secondly, the project showed that use of graphic animation is not complicated. It assists in performance improvement of the students. This means that the cognitive achievement in the learning process is positive. The focus group that used graphic motion performed far better. It was noted to be the same case for individual schools sampled.

Thirdly, according to KICD new policy of competence-based curriculum, examinations will not be abolished but rather be tailored towards accessing the ability of learners to apply learnt skills. The project finding, that graphic motion animations enhance acquisition of skills, aligns with this policy. This was evident from the analysis of tasks performance of the focus and control groups.

The fourth aspect was on syllabus coverage. It has been a challenge for teachers to complete science syllabus in time, especially Physics in Kenya. Hence, time saving is of great importance. If syllabus is covered on time, learners will have enough time for practice and review of learnt concepts. The project was able to show that use of use graphic animation saved time and ten lessons saved in a year, through data analysis of time.

Lastly but not least, the Kenyan Government efforts for 100 percent transition to high school can be enhanced through adoption of the aspects that this project has addressed. Resources for learning and teaching can be eased by having this facility as a compliment.

**Recommendations**

This project proved that if graphic motion animations are used and integrated in our education system as a policy, it would be of great importance to education and Kenyans. Education stakeholders can prepare policy framework, with the right technologist in ICT integration to come up with a common platform. The education ministry could pick up, the project and do the backbone action for this project, which is provision of the required ICT devices in schools. The TSC could also start focusing on the right pedagogy training through their new Teachers' Professional Development (TPD) courses.

At the end of it all Kenyans will benefit a lot by saving funds and skilled work force hours.

**Recommendations for further research**

Further research on this area of animation is recommended which should focus in each category of animations. Secondly; the research that nets a wide range of schools in Kenya could be of significance if it is done in good time, in order to get a good picture of the effects of animations in teaching all subjects in the country.

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**Article 36**

# Use of various ICT tools in teaching and learning of Science

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**Abstract**

Education systems globally are revolutionizing pedagogical methods, improve management of education and expand access to quality education to integrate Information and Communication Technology (ICT) in teaching and learning.In order to bring socio-economic development, the role of ICT in Science education cannot be overemphasized.Some of the benefits of technology include: promotes personalised learning, hands on and interactive learning, it gives the learner instant feedback on assessments and make learning more flexible. The Botswana government has launched a number of major initiatives to support transformative vision and to promote the use of ICT in teaching and learning and through ETSSP it has identified and prioritized digital learning. A mixed method research designed was used in this study. Data was gathered through interview, document analysis and classroom observation from a population of 270 students and two teachers. Data was analysed thematically. The findings revealed that interactive video enhances understanding of scientific concepts. It also demonstrated that the use of ICT improves students' performance in Science. But besides these findings, several challenges on ICT have been observed, which include, among others; lack of ICT skills, limited to no resources, ICT phobia by teachers, congested syllabus and high teaching loads. It was recommended that the Government of Botswana invest more on ICT resources and facilities in order to appreciate the impact of ICT on learner performance.

**Key Words:** *ICT, Teaching, Learning, Digital, Integrate. Video*

## Introduction

Globally, education systems are adopting new and various technologies to integrate Information and Communication Technology (ICT) in teaching and learning process. Technology forms an important part to today's learner and the world is taking advantage of technological affordability to enhance learning by making it fun, more meaningful, interesting and appealing to ensure learner success. This approach helps inculcate the 21$^{st}$ century skills needed by the learner in preparation for the 4$^{th}$ Industrial Revolution, which are collaboration, critical thinking, creativity and communication. This enables teachers to evolve from the traditional way of delivering instruction which is teacher-centric to the modern way which is learner-centric.

ICT include software and hardware which are essential in delivering audio visual, printing and video services. According to Kolu and Ekwueme (2003), the computer is the key instrument in globalization. Computer communication is increasingly becoming a fact of everlasting life mostly in some developed and developing countries. In both developed and developing countries ICT has significantly changed how people work, live, teach and learn. Akadolu (2002), states that ICT is changing every part and aspect of human life, education, security, entertainment, culture and communication services.

According to World Bank (2001), ICT holds the opportunity to revolutionize pedagogical methods, improve management of education and expand access to quality education. It has been observed that the current pedagogical/pattern used in most African countries does not really prepare students for the competitive global world of information and technology. The pedagogical patterns do not equip learners to fit nor soar effectively in the contemporary times of Science and Technology. Current thinking about ICT in education suggests that while traditionally important pedagogical practices are still dominant in Science education, ICT contributes to innovative pedagogical practices (Voogt, 2009).

## Statement of the problem

The role of ICT in Science education cannot be overemphasized. Some of the benefits of ICT include: promotion of personalised learning, promotion of hands on and interactive learning, giving the learner instant feedback on assessments and making learning more flexible. The Botswana government has launched a number of major initiatives to support the digital transformative vision and to promote the use of ICT in teaching and learning. However, it is evident that performance in Science has been very poor over the years and is continuing to fall down. This research paper is trying to bring technological pedagogy to enhance teaching and learning of Science.

## Objectives and research question

The paper aims to access the impact of the use of ICT on students' understanding of Science. It is also to establish if the use of ICT enhances performance in Science. This paper will find out the challenges experienced by teachers in the use of ICT in teaching and learning.

## Research questions and hypothesis

1. What are the effects of using interactive video tool on students' understanding of Science concepts?

   **Null hypothesis:** Interactive video tool does not significantly enhance understanding of Science concepts
2. What is the impact of ICT on students' performance in Science?

**Null hypothesis:** ICT integration does not have a significant impact on student's performance

3. What are the challenges of the use of ICT in teaching and learning?

**Literature review**

This chapter provide an overview of literature around the use and the importance of ICT in education in general, be it educational policies, teacher training and teaching and learning. The conceptual framework of this study is also stated in this chapter.

**ICT in education –an overview**

According to Ibe – Bassey (2011), ICT is regarded as an important tool for preparing and educating learners with the required skills for global work place. It is a set of technological tools and resources used to manage information and communication. According to Anthony (2012), the impact of ICT in education include the following: ICT gives access to information and knowledge, ICT makes sharing and serving knowledge easier and ICT removes problems concerning time and space.

According to Bell and Margaret (2006), the benefits of ICT in education include amongst: Interactive learning and joyful, global access to information and knowledge, self-based learning, sharing of experience and practice, exponential learning, excitement and motivation.

**Policy perspectives on ICT**

Sustainable use of ICT in Education, both in developed and developing countries at policy level, can be summarized as: ICT is an essential life skill, ICT is a tool for educational management, ICT can improve teaching and learning and ICT provides opportunity for economic developments. Kozma (2008), has identified four rationales in advancing the use of ICT in education. These are: to support economic growth, promote social developments, advance educational reforms, and to support educational management.

According to Kozma (2008), these policies require operational components such as: Infrastructure developments. (This include budget and technical resources), teacher training (teacher professional development programmes). Technical support (both hardware and software), Pedagogical and curriculum change (ICT related changes in curriculum) and lastly content developments.

**Importance of ICT in education**

Trinided et al (2001), summarized the importance of ICT in education as:

- Using computer generated graphics to show relationship of different dynamic processes.
- Promoting students intellectual capabilities through problem solving, critical thinking and deep understanding concepts.
- Promoting interactive teaching and learning environment.
- Promoting supportive learning to students with special needs.
- Improve school attendance.

- Promoting learner centered teaching and learning approaches.
- Empowering learners with ICT awareness and skills required for knowledge economy
- Improving quality of education and instructions.
- School transformation and improving school management.
- Encouraging collaborative learning.

**ICT in Botswana**

The government of Botswana has a national ICT policy called Maitlamo which provides a road map to drive social, economic, cultural and political transformation through the effective use of ICT. Maitlamo aims to provide a communication network to ensure that the country has the skills to be an ICT leader. The policy's key goals are for Botswana to become a sub-Saharan ICT hub, to create an enabling environment for the growth of an ICT industry in the country and to provide universal access to internet and communication facilities in the country

The most ambitious strategy in education and ICT, is the Botswana Education and Training sector Strategic Plan ETSSP (2015 - 2020). The plan marks a significant milestone in Botswana as a nation to bring about a more diversified knowledge based economy. (ETSSP) from early childhood to tertiary and vocational education. These are lifelong learning, ICT, curriculum development, human resource development, and education management and information system reforms.

**ETSSP and Thuto net**

Botswana has made some considerable efforts in the transition from a traditional agro-based economy to the industrial economy. ETSSP support implementation of Thuto by providing schools with high speed internet access, increasing computers to students' ratio in schools, designing and implementing an ICT content and curriculum developing program for primary, secondary, vocational and tertiary, utilizing e-learning.

Botswana government established the Botswana innovation Hub to foster high technology business and commercialize ideas for sustainable economic growth. One of the key objectives of the innovation hub is to assist home grown innovators with targeted inventions to achieve scalable operations.

**The role of ICT in Science education**

At present, teachers' motivation to use ICT in teaching and learning is adversely affected by a number of factors including: limited access to reliable resources, lack of confidence and experience with technology, lack of subject- specific guidance for use of ICT in teaching and learning, so integration and effective use of ICT is currently rare in most countries.

Mostly teachers tend to use ICT to support and complement existing different classroom practices as opposed to re-shaping goals, pedagogy and subject contacts. According to Osborneet (2003), training teachers in ICT appears to have more benefits or success in Science than other subjects.

Teachers are now developing new strategies which overcomes the distraction of technology and focus attention on intended learning outcomes.

**Conceptual framework**

This study adopted the Four in Balance Model as its conceptual framework. This model is used to investigate the value of pedagogical use of ICT in teaching and learning. The model proposes that the effective use of ICT in teaching and learning requires four basic elements.

**Vision**-the school's view of what constitutes good teaching and how the school aims to achieve it. This involves the school's objectives, the role of the teachers and students, the actual teaching content, and the materials that the school uses.

**Expertise**-teachers and students need to have sufficient knowledge and skills in order to utilise ICT to achieve educational objectives.

**Digital learning materials**-all digital educational content for both formal and informal constitutes digital learning material. This includes computer programmes.

**ICT infrastructure**-the availability and quality of computers, networks, and Internet connections constitute infrastructure facilities. Also electronic learning environments and the management and maintenance of the school's ICT facilities are also taken to be part of the ICT infrastructure.

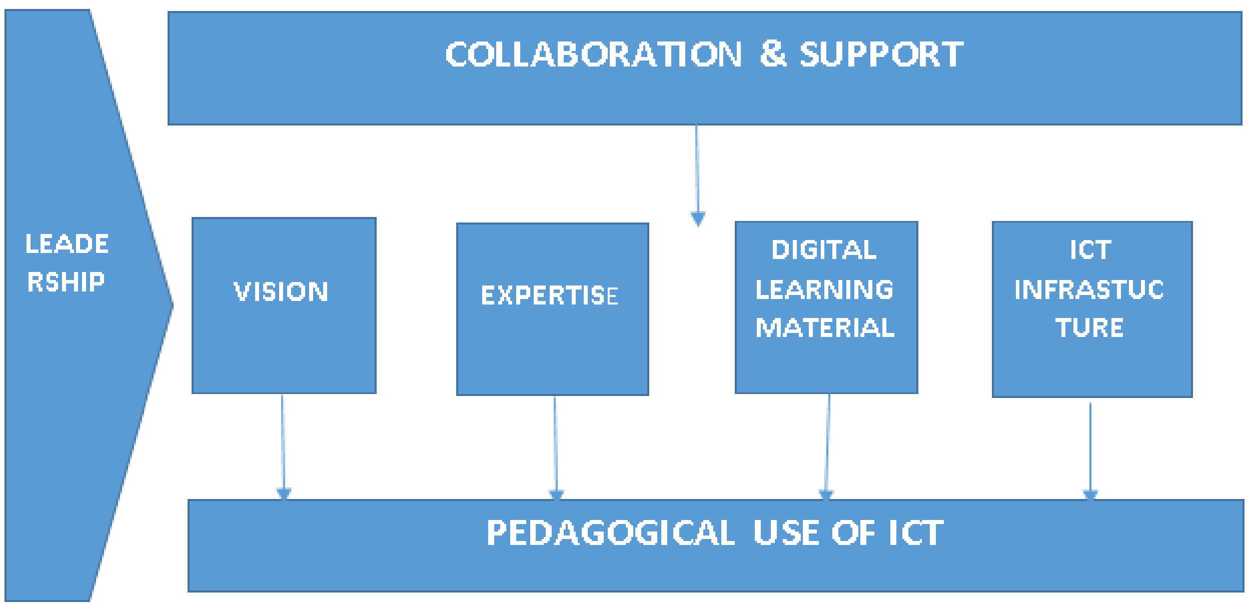



*Figure 1 Four in Balance Model*

Collaboration of teachers and school management support as well as leadership is very vital in this model. The teachers' pedagogical knowledge of content cannot be overemphasized in this regard.

"Pedagogical content knowledge refers to knowledge about a topic that enables improved teaching of that discipline. In Science, such knowledge involves an understanding of the ideas students bring to class, the context in which students apply their Science knowledge, and the multiple models of the same topic used by students and experts in the various contexts of application" (Linn & Hsi, 2000, p. 337).

## ICT in Science education-implications

In order to bring socio-economic development, the role of ICT in Science education cannot be overemphasized. Developments can only be made meaningful if they are driven by science in education. The success of ICT in Science education depends on adequate funding, teacher professional development, and improved working conditions of Science teachers. This directly contributes to good quality education, monitoring and evaluation by both the government and educational management. Teacher Pupil Ratio- this is a major challenge in the realization of ICT in science education, teaching methods- teachers must shift from teacher centered approach to learner centered approach. Mbukwe (2005), argued that teaching methodology is what makes a teacher a professional.

## Methodology

This chapter presents overall design of the study, description of variables, participants, data collection instruments and data analysis.

## Research Design

In this study, a mixed method design was adopted. Tashakkori and Teddie (1998), defined mixed method as the combination of qualitative method and quantitative methods in research. The mixed methods enabled the researcher to use different approaches to answer research question and therefore it was not limiting. This made it pluralistic, inclusive and complementary as it gave the chance to find out useful answers. The elements of quantitative and qualitative were combined in this study for depth understanding and corroboration.

## Qualitative Data Instruments

Qualitative data was gathered through an interview with ICT teacher in the school. Note taking was used during the interview which were conducted individually. The interviews consisted of open ended questions related to the use of ICT in teaching and learning of Science. This was mainly on challenges experienced by teachers on ICT integration, material and resources, internet connectivity and the general condition of the ICT lab in the school. Written documents were used to obtain more detailed information. The data collection instruments were developed by the researcher himself.

## Quantitative Data Instruments

Quantitative data was gathered through document analysis of students' results. Also an experiment was conducted to compare the impact of interactive video on understanding of the science concepts. Interactive video is a type of digital video that supports user interactions. It has clickable links and conducts formative assessment. One class with a total of 45 students was taught a Science topic (The Structure of the Eye), using an interactive video and the other class taught without an interactive video. At the end, both classes were assessed to find the impact of interactive video in understanding of the concept. An independent sampling ‘T’ test was used to analyze the results.

**Qualitative Data Analysis**

Qualitative data in this study came through interview and class observations. Qualitative data was analyzed by thematic data analysis approach. According to Attride-Striling (2001), thematic analysis as a flexible method that allows analysis of qualitative data that was collected through observations and interviews. Thematic analysis was used to systematically identify patterns and meaning of data collected from interviews.

**Quantitative Data Analysis**

Quantitative data from students’ marks was analyzed using excel. Quantitative data analysis allows the reporting of summary results in numerical terms. Data from respondents was entered in excel and descriptive statistics was used to analyze the data.

**Sampling**

A purposive sampling was conducted with teachers and students. The main focus was on a particular characteristic of a population that is of interest. According to Patton (2002), in purposive sampling, the researcher first identifies subgroups of the population of interest and then selects cases from each subgroup in a purposive manner. Senior teacher for computer studies was selected as she has experience in the area of ICT. One Science teacher who has experience in ICT integration was also selected in this study together with the 4 classes that he taught from 2016 to 2019.For 2016 & 2017 classes, there was no integration of ICT while for 2018 & 2019 there was integration of ICT in teaching and learning.

**Population size**

A population is a group of people which the sample is drawn from and the researcher would compare the results of both samples. This study consisted of 1 Senior Teacher ICT, 1 Science Teacher and a total of 6 classes giving a total of 270 students.

**Ethics**

The researchers had the responsibility to protect participants through the research (Creswell, 2003). Participant’s names were not disclosed except only the school in which the study was conducted. There were no rewards and issues of confidentiality and anonymity were adhered to.

**Results**

This chapter report and presents findings of the study. The findings were presented in tables and graphs.

Interactive video and understanding of concepts

The data from formative assessment of interactive video revealed that there is a significant improvement on the way the students understood the concept of the model of an eye as compared to the class that was not taught using the interactive video. A sampling T-test was used to analyze the mean scores of the performance of the two classes

*Table 1 Independent Sampling T- Test*

| Variables | NO | Mean | Std D | Sig |
|---|---|---|---|---|
| class | | | | |
| 3C | 44 | 17.0 | 3.35 | |
| 3E | 46 | 19.2 | 4.5 | 0.004 |

Data in the table 1 shows that there is a significant mean difference of performance among the two clases.3E class understood the concepts easily through interactive video (mean 17.0) as compared to class 3C in which interactive video was not used. The standard deviation of the 3E class was found to be 4.5 which is significant as compared to 3.35 for the other class.

**ICT and performance**

The data of student's performance from 2016 to 2019 was statistically analyzed using excel software and the results are shown in the figure 2 below. The performance of classes taught using ICT (2018 & 2019) was compared with the performance of classes taught without ICT (2016 & 2017).

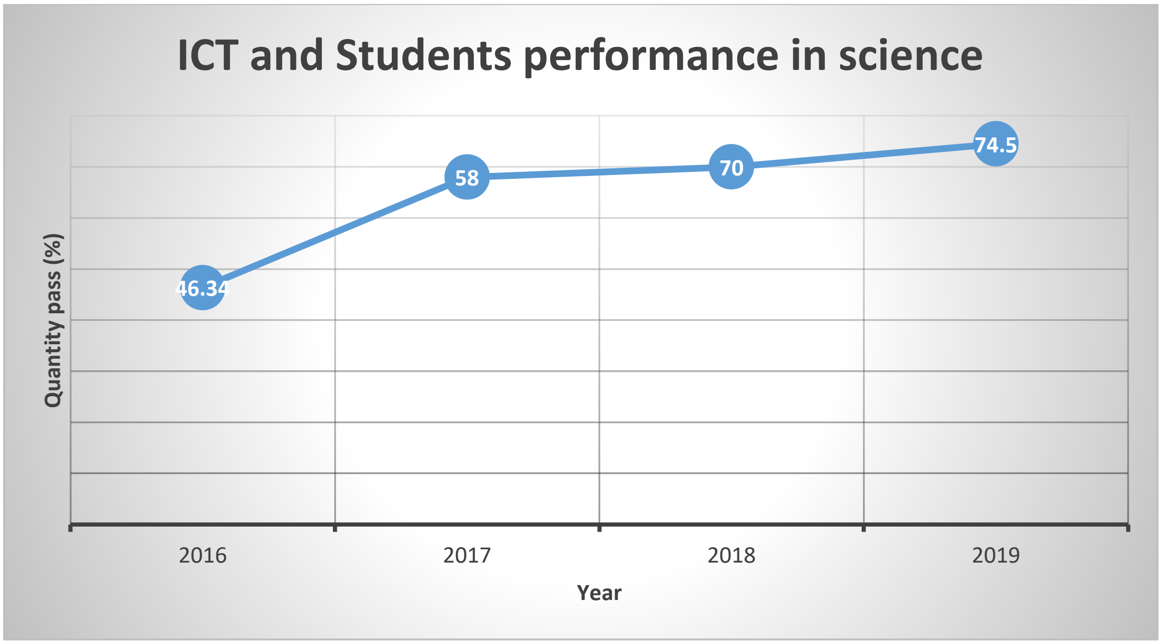


*Figure 2. ICT and performance of various classes*

Data in figure 2 above shows that there is a significant improvement in performance amongst students who were taught using ICT as compared to their counterparts. An average of more than 70% for classes that used ICT in teaching and learning as compared to an average of close to 50% of classes that did not use ICT in teaching and learning of Science

*Challenges in ICT*

Data from the interview with the Senior Teacher revealed that Teacher's motivation to use ICT in teaching and learning of Science subject is at present, adversely affected by a number of factors or constraints including; lack of ICT skills and resources, ICT phobia, congested syllabus and high teaching loads which also results in lack of time to gain confidence and experience with technology. She revealed that the use of ICT motivates both the teacher and the learner. The data revealed that a lot of training for teachers on the use of ICT has to be done. This will equip teachers with relevant skills for integration of ICT in teaching and learning. As part of the interview, a data form was used to capture available ICT resources in the school and particularly those used by teachers and students as shown in table 2.

*Table 2. Availability of ICT resources in Kgale Hill Secondary*

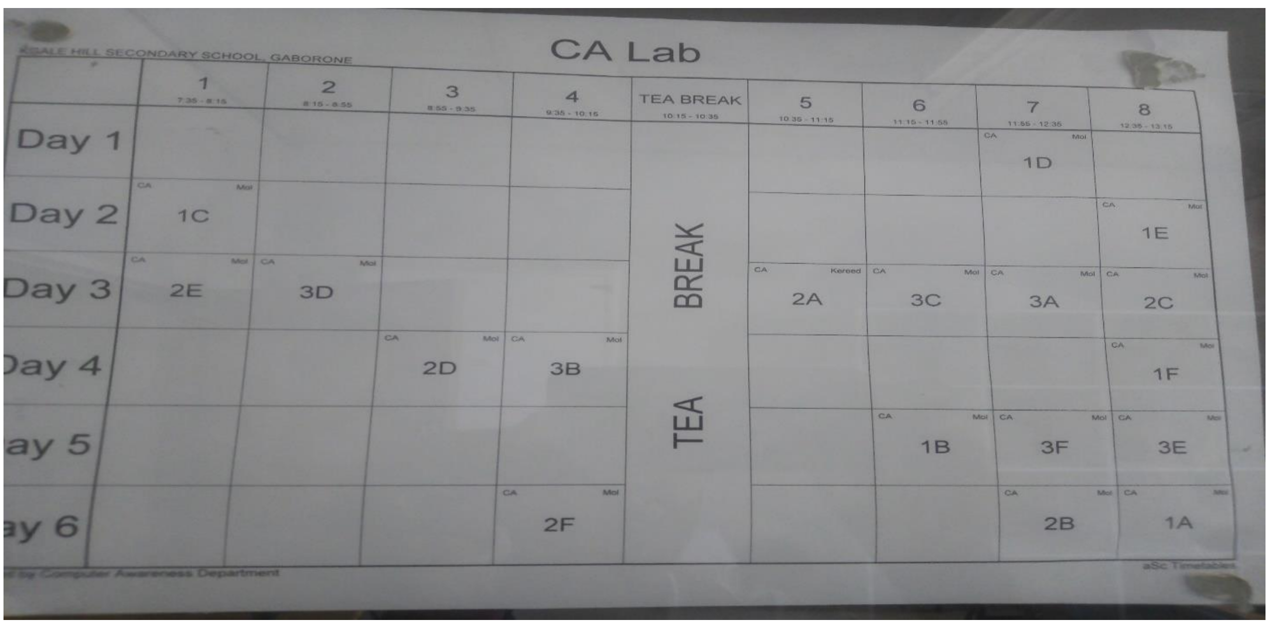
| ICT tools | Total | Working (%) |
|---|---|---|
| Computers | 50 | 50 |
| Tablets | 50 | 0% |
| printers | 4 | 50 |
| flip boards | 0 | 0 |
| Scanners | 1 | 100 |
| Projectors | 3 | 33.3 |
| ICT Lab | 1 | 100 |

Data in the above table shows that there is serious shortage of resources. The data revealed that only 50% of computers are working and none of the tablets are working. Since there are about 800 students in total, the computer student ratio is found to be 1:14. This indicates a severe shortage. Then table 2 also revealed that only one projector is working, so this means only one teacher can use a projector at a time. The data from table 2 shows that there is only 1 ICT lab in the school. This means that only 1 class out of 18 can access the ICT lab at a given time.

## Internet connectivity

The data obtained from the interview revealed that there is a slow and unreliable internet in the school. This on its own according to the teachers, affects the delivery of instruction and makes it difficult for teachers and students to access the internet. Generally, digital tools require strong and fast internet. Furthermore, Science videos comes in big files which requires a high capacity bandwidth (minimum of 4MB). It has been revealed that the internet is slow during the day as most teachers and students will be accessing it. The teacher confessed that this makes it difficult for them to be innovative to leverage technology to improve teaching and learning.

A picture of the ICT timetable below shows how congested the classes are and the teaching loads. One teacher is given all the ICT lessons and these are mainly for Computer Awareness to the learners and not ICT integration. Subject teachers rely only on the free slots to use the Computer lab and integrate ICT into their subjects. The teacher revealed that the availability of the few slots in a day from the timetable affects usage of ICT in teaching and learning of other subjects.


CA Lab

| | 1 | 2 | 3 | 4 | TEA BREAK | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| Day 1 | | | | | TEA BREAK | | | 1D | |
| Day 2 | 1C | | | | | | | | 1E |
| Day 3 | 2E | 3D | | | | 2A | 3C | 3A | 2C |
| Day 4 | | | 2D | 3B | | | | | 1F |
| Day 5 | | | | | | | 1B | 3F | 3E |
| Day 6 | | | | 2F | | | | 2B | 1A |

*Figure 3. Computer Awareness time table for all classes*

## Discussion, conclusion and recommendations

### Discussions

The findings in figure 2, shows there is a significant improvement in performance amongst students who were taught using ICT as compared to their counterparts. An average of more than

70% of classes that used ICT in teaching and learning as compared to an average of close to 50% of classes that did not use ICT.

Kuliks (1994), posit that on average, students who used ICT based instruction scored higher than those without ICT based instructions. He further argued that students learned more in less time and enjoyed their lessons more when ICT was integrated in their learning. ICT is regarded, by Ibe – Bassey (2011), as an important tool for preparing and educating learners with the required skills for global work place

Fuchs and Woessman (2004), argued that ICT constitutes input in students learning process that could help produce better results. They lamented that ICT enhance learning by making education less dependent on teachers. ICT positively transmit knowledge and skills to learners and it helps learners to explore some other possibilities for acquiring information, and this increases learning and communication.

Schools need access to fast and reliable internet. Researchers disclosed that unreliable internet can restrict lesson delivery and can even stifle innovation in classroom. This unreliable and slow internet will prevent schools from moving into advanced technologies such as online testing. Online testing gives immediate feedback and saves a lot of time as compared to traditional standard tests and examination. Similarly, large class sizes make it difficult for the teacher to mark and give students feedback immediately. The formative assessment in the interactive video is a clear example that online testing can be ideal. Despite the support by ETSSP and Thuto Net to provide schools with high internet access and increase computer to students' ratio, there is still a serious problem in schools.

The findings in table 2 displays scarcity of resources. The findings revealed that only 50% of computers are working and none of the tablets are working. Since there are about 800 students in total, the computer student ratio is found to be 1:14. This makes it difficult for teachers and students to access learning materials.

According to Osborne and Hennessey (2003) the shortage and limitation of resources affect teacher motivation to use ICT in classroom. It is found that though computers are very few, (50%) of some teachers improvise and bring their own laptops for better teaching. However, low speed internet, virus threat and software problems makes it difficult for teachers to access digital media tools to enhance their teaching and learning. These include interactive video, digital storytelling, Kahoot and other programs.

The Senior Teacher ICT advised that teachers have to be provided with computers and projectors for proper planning in order to make the best out of ICT in teaching and learning process. She however stated that some software are not easy for teachers who have limited skills on ICT, hence the advice on proper training to be done frequently. This will address the problem of technophobia.

According to Kozma (2008), education needs policies that require operational components such as: Infrastructure developments. (This include budget and technical resources), teacher training (teacher professional development programmes). Technical support (both hardware and software), Pedagogical and curriculum change (ICT related changes in curriculum) and lastly content development.

Becta (2004), emphasizes the importance of pedagogical training as she argued that pedagogical training is more important than just simple ICT training. The pedagogical content knowledge of teachers cannot be overemphasized in this regard

"Pedagogical content knowledge refers to knowledge about a topic that enables improved teaching of that discipline. In Science such knowledge involves an understanding of the ideas students bring to class, the context in which students apply their Science knowledge, and the multiple models of the same topic used by students and experts in the various contexts of application" (Linn &Hsi, 2000, p. 337).

**Conclusion**

The paper examined the impact of ICT in Science education in Kgale Hill Secondary School. The paper highlighted the overview of ICT in education and the role of ICT in Science education. ICT promotes intellectual qualities and communication skills in students. Considering the findings of the study, it can be concluded that ICT have a significant impact on learner performance and general understanding of Science concepts. Therefore, both of the two null hypothesis are rejected

**Recommendations**

Based on the findings, the following recommendations were given

1. The Government of Botswana should put more resources and facilities on ICT.
2. The Ministry should show interest in the use of ICT for effective learning of Science and other subjects across the curriculum.
3. The school management and teachers should recognize the impact of ICT on learner performance and as a tool for authentic learning.
4. Students should have access to a high bandwidth internet. This will allow them to learn on their own and access some interesting e-learning tools.
5. Science teachers should recognize and appreciate the use of ICT and other media technologies in teaching and learning of Science

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**Article 37**

# Challenges facing the implementation of NEPAD pilot e-schools' initiative in Kenya

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**Abstract**

NEPAD e-school project aims at imparting ICT skills to Primary and Secondary schools' children to improve access to education in Africa. In Kenya, the pilot phase was initiated in six secondary schools in the year 2004, namely Mumbi Girls, Isiolo Girls, Menengai High School, Chavakali Boys, Wajir Girls, and Maranda Boys. It was found out that majority of the teachers have not undergone the in-service training in the field of ICT, most students and teachers do not access the e-materials and finally most teachers and students lack the expertise and skills to handle both hardware and software of the e-materials. All the six Schools were included in the study and the teachers and students formed the study population. The study employed survey research methodology. Data was collected using survey questionnaires whose validity was tested then data analysed using SPSS. This suggested that teachers need to be in-serviced on the use of ICTs in the teaching and learning. The ministry of education should provide enough e-materials for all teachers and students. The paper recommends that further research be done in other schools in which such ICT programs are being implemented to curb the loop holes in its implementation and to establish the quality of the software and hardware suitable for educative purposes in schools.

**Keywords:** Challenges, Learning, NEPAD, Performance, Policy, Programme

## Introduction

### Purpose of the Study

The purpose of this study was to investigate into challenges facing the Implementation of ICT programs in the six NEPAD pilot E-Schools in Kenya. The overarching aim of the study was to undertake an empirical evaluation of the challenges facing successful implementation of NEPAD's pilot e-Schools in Kenya. This is specifically to: establish the skills and expertise of teachers and students as pertaining to ICT in the e-Schools; determine the infrastructure, accessibility for enhancing teaching and learning; investigate the effectiveness of the training imparted on teachers and students; establish the extent to which e-School infrastructure is being used to enhance teaching and learning and to determine the extent to which the e-Schools are preparing students to function in the global economy.

**Objectives of the study**

Specifically, the study was guided by the following objectives:

a) To establish the extent to which the teachers are trained and qualified to handle the e-School facilities.

b) To identify the level of expertise and skills possessed by teachers and students in utilizing ICT facilities.

c) To establish the extent to which the e-School facilities are being accessed and used for classroom instruction during lessons.

**Methodology**

**Sample size**

A sample is a part of the population that is used to represent the whole group when research is being done. 18.5% of teachers and 10.5% of students of the target population was sampled since a study sample in the range of 10% - 20% of the total population is acceptable as a sample in descriptive research. A total of 246 students were sampled in which 135 were form two and 111 were form three out of the 2330 students which was the total population of the six NEPAD e-schools, this represent 10.5% of the total population of students who were sampled for the study. 61 teachers out of 324 teachers were sampled which was 18.5% of the teachers' population as shown in table 3.3:

**The sample size of teachers**

| | **School** | **Teachers** |
|---|---|---|
| 1 | Maranda Boys | 13 |
| 2 | Chavakali Boys | 14 |
| 3 | Menengai High | 10 |
| 4 | Mumbi Girls | 9 |
| 5 | Isiolo Girls | 8 |
| 6 | Wajir Girls | 7 |
| | Sample Total | 61 |

From the table above, it can be observed that the total sample population of teachers was 61 out of a total population of 324 representing 18.5% of the target population. Therefore, this sample is acceptable.

**The sample size of students**

| | School | Form Two | Form Three |
|---|---|---|---|
| 1 | Maranda Boys | 37 | 32 |
| 2 | Chavakali Boys | 42 | 33 |
| 3 | Menengai High | 23 | 18 |
| 4 | Mumbi Girls | 17 | 13 |
| 5 | Isiolo Girls | 9 | 8 |
| 6 | Wajir Girls | 7 | 7 |
| | Sample Sub Total | 135 | 111 |

The total sample population of students was 246 out of a total population of 2330 representing 10.5% of the target population.

**Research Instruments**

The study used questionnaires to collect information from teachers and students. An interview guide was used to get information from the Principals.

**Questionnaires**

Questionnaires were used as main instruments for data collection. According to Orodho (2008) questionnaires are extensively used to gather data on current conditions, practices, opinions and attitudes quickly and in a precise way. Mugenda (2003) argue questionnaires provide a cheap way of obtaining information from a large number of populations. The questionnaire allowed measurement for or against a particular view point. A questionnaire has the ability to collect a large amount of information in a reasonably quick spell of time. Through use of questionnaires, information can be collected from a large number of people and the questions can be easily analysed, and it allows anonymity (Orodho, 2009). The questionnaires were filled by both teachers and students. In this study questionnaires were convenient because all the teachers and students in the sample were literate and therefore were able to fill the questionnaire without difficulty.

The two questionnaires, for the teachers and students collected demographic data, the level of expertise for the teachers and students on the extent of e-learning implementation in the schools and on teachers and student's accessibility to the e-materials in the school. The questionnaires were administered to the Students which was a sample of 111 for form threes and another 135 for form twos and a sample of 61 teachers from all the six NEPAD schools.

**Interview guide**

The interview guide was only meant for Principals who were only to answer questions on the population of teachers and students; the Principal was supposed to give the total number of students in the school, then give the number of form two and form three students. He or she was also to give the number of teachers and students the school has in terms of gender.

**Findings**

**Introduction**

This study looked at the extent to which the teachers are trained and qualified to handle the e-School facilities, to determine the level of expertise and skills possessed by teachers and students to handle e-school facilities and to also find out the extent to which the e-School facilities are being accessed and used for classroom instruction during lessons. The study also highlighted the achievements and challenges facing the e-School project. This section gives a summary of findings and conclusion of this study. The chapter ends with a list of suggestions for further study.

**Professional and academic qualifications of the teachers**

**a) Professional and academic qualifications**

With regard to academic and professional qualifications, the researcher observed that most of the respondents are graduates of with either a university degree or a master's degree, which indicates that the respondents are highly qualified to grasp content in ICT training with ease. Secondly, being qualified, the teachers can spend more time experimenting with methodology, rather than content.

**b) The qualifications of teachers in ICT**

The study observed that the teachers are deficient of adequate training and competence in the use of ICT. Teachers who are not well trained in ICT will shy off from utilizing such resources in classroom instruction.

Secondly the study revealed that few teachers have received ICT training just three years ago, meaning that most teachers are not updating on the ICT knowledge they received before joining the teaching profession.

**c) Competence of teachers to handle the e-School facilities**

This study observed that a high proportion of teachers do not have adequate skills to handle the hardware facilities and have difficulties in handling the installed software. Without skills in using the installed programs teachers cannot facilitate their lessons using the e-learning approach.

The study further observes that all the teachers are trained to make basic computer files using a word processing program, spreadsheet and database management programs. The three areas form the basics of ICT training forming an opinion that the respondents are trained in the basics of the technology. This study also revealed that all respondents require more training on how to utilize ICT resources for classroom instruction.

**Extent of use of ICT resources by teachers**

This study revealed that there is inadequate use of ICT resources in almost all areas. The inadequate use was observed to be due to three factors.

Firstly, the ICT laboratory is fully engaged in the teaching of computer studies which is being offered to few students, so teachers can only access the facilities when such a room is not being used for any other purpose. The computer studies are given a first priority, and teachers must postpone their priority until such a time when they are free and the ICT resource room is free.

Secondly, the computer studies teachers are fully utilizing the ICT facilities when teaching Computer studies, but the use of the resources to further the other objectives of the NEPAD e-School project, e.g. harnessing ICT technology to improve, enrich and expand education, was observed to be at minimum.

The study further revealed that a major impediment to ICT adoption and utilization is because the relevant programs tailor-made for the Kenyan schools are non-existent. In some cases, only fragments of the syllabus can be covered by use of ICT. The existing programs are based on foreign syllabi or too detailed beyond the level of the student.

Lastly, the study revealed that the low key utilization of ICT resources by teachers was due to inadequate exposure to technology. Most teachers are not experts in the use of ICT resources.

**The E-School Hardware and software in relation to access to ICT**

Concerning hardware this study made the following observations, firstly e-School facilities are not being used for e-learning in the strictest sense, rather as facilities for learning computer studies. Teaching computer studies is just a fraction of the objectives of the NEPAD e-School facilities. The provision of a forum for newly emerging e-learning approach is being overlooked to a large extent.

Secondly, the placement of the ICT resources in one ICT laboratory and overlooking rooms like the library is greatly limiting access. A centralized room can only be accessed one at a time. Teachers and students must wait until a computer lesson is over and when they are not attending another lesson.

Relating to software, this study made two observations: First, none of the programs installed are homemade or tailored to meet the objectives of the Kenyan secondary school syllabus. The teachers and students have to sieve through the existing programs until the desired content is achieved. This by itself has a time element which teachers are resisting. Secondly, private software developers are making their own programs and infiltrating into schools and sell those programs. The contention to this observation is that policy issues relating to ICT should be developed and implemented in the strictest sense.

**Conclusion**

Based on the findings of the research it was concluded that there were a number of challenges facing effective implementation of NEPAD e-schools. These challenges included: lack of trained teachers in the field of ICT and if trained there has been no effort in in servicing the teachers on ICT integration in teaching and learning. It was also found out that due to the poor teacher qualification in the area of ICT, there is no expertise and professional skill by teachers in handling e-materials and therefore consequently students lack ICT skills. For the few e-materials available in e-schools, accessibility to these materials by teachers and students is poor. If these three components; teacher training, expertise and accessibility, are not addressed, then there is no way students will graduate from high school with ICT literacy

**Recommendations**

This study revealed issues that led to the following recommendation

1. While in-service for practicing teachers is recommended, this study suggests that student teachers must be oriented towards ICT adoption right from their first year in campus so that they can be well versed with ICT skills before they graduate. The student-teachers need to try out their ICT skills in lessons during microteaching, teaching practice and during their actual practice.

2. A revision of the teacher training curricular must be considered with a view of orienting it to the emerging issues in ICT.

3. The study proposes a comprehensive in-servicing oriented towards ICT for all teachers. The training should be voluntary, and viewed as part of teacher professional development, which should be used as criteria for promotion. Those lacking ICT skills, and those showing resistance to its use, should be demoted or phased out from service.

4. This study proposes that all NEPAD pilot schools be declared regional ICT support centres when the project is adopted nationwide to help other schools come up with e-learning programs.

5. In order for students and teachers to access these e-materials the schools must put the ICT in place. All students and teachers should be free to handle ICT materials.

**Suggestions for further research**

1. The study restricted itself to the study of the NEPAD e-School project. Other schools under a different ICT program were not covered. There is need for a study that can explore the achievements and challenges of other ICT programs in Kenyan schools.

2. The study did not address the details of the suitability of educational software, which form the core element of ICT use in education. There is need for a study to exhaustively cover the suitability

of the existing education software with a view of providing sound recommendations to policy makers and program developers.

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**Article 38**

# Pupils' attitude towards learning measurement concept: A case study of Ndii-ini primary school, Ruiru sub-county, in Kenya

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**Abstract**

The main aim of this study was to find out the various attitudes experienced by pupils in the middle- upper primary, while learning measurement concepts in Ndii-ini primary school in, Ruiru Sub-county, Kenya. Attitude is a disposition towards an aspect of Mathematics education that has been acquired by pupils through their beliefs and experiences but which could be changed. The study adopted a descriptive research design. The study used simple random sampling in selecting thirty (30) pupils in class Five. Observation Schedule and unstructured interview schedules were used to collect data. The study was carried out in Ndii-ini primary school. Data were analyzed using R-instat. From the study, the findings, were that most pupils were not able to comprehend and perform Mathematics tasks, because of negative attitudes towards learning measurement concepts, lack of learning materials and Mathematics language. The learning environment was not conducive, it lacked learning materials that could enhance their learning of measurement concepts. The study recommends that Mathematics language should be part of Mathematics teaching, the government should increase funding of learning materials in primary schools and come up with modules to aid the in-service courses, and this will improve on their methodology in teaching Mathematics.

**Keywords:** *Pupils attitudes, Mathematics Education, Learning environment, confidence*

## Introduction

Mathematics is a compulsory subject taught at all levels of education from primary school level to a higher level of education in Kenya. Mathematics education, since its introduction in 1965 has been evolving. Currently Mathematics educators in primary schools are facing challenges in implementing the Competency-Based curriculum which was launched by the Ministry of Education in 2017. The Competency-Based Curriculum was designed to emphasize the significance of developing skills and knowledge and also applying those competencies to real-life situations. In the lower primary the purpose of Mathematics is to prepare pupils for number work and Mathematics higher levels of learning. In upper primary Mathematics involve understanding numbers and the numerical operation used to develop strategies for mental Mathematics, estimation and computation fluency and to boost positive attitudes towards teaching and learning of the subjects.

**Pupils Attitude towards Learning Measurement Concepts**

Attitude is a commonly used term in the Mathematics education literature as well, yet it is a concept difficult to define precisely. The term has been used interchangeably with others such as Mathematics anxiety, which refers to feelings of tension interfering with the individual pupil's ability to solve mathematical problems in different Mathematics contexts. However, attitudes towards Measurement concepts, just like other types of attitudes, do not necessarily entail negative feelings, they are defined more broadly. The attitude in learning measurement is also conceived as a matter of liking or disliking the subject, i.e., an emotional disposition to the subject, others have argued that a multidimensional explanation including cognitive and affective aspects provides a better understanding (Can, koydemir, Durhan, Ogan, Gozukara & Cokluk, 2017).

The cognitive component of attitude is what the pupils think or believe about measurement. The affective component of attitude is the feeling or emotions of the individual pupil, associated with learning measurement. Thus, the affective component is the source of driving the engagement of pupils towards learning measurement concepts. Furthermore, the affective aspect is also influenced by the belief formed from the cognitive component of attitude, which creates a mindset that becomes constant over time and influences the feelings of the pupil towards learning measurement. As such, the cognitive and affective components of attitude are interrelated and deeply interact with each other (Sanchal and Sharma, 2017).

According to Piaget's theory of cognitive development, pupils between the ages of 7 to 11 years are at the concrete operational level. They can comprehend the principle of conservation which permits them to understand mathematical concepts in measurement. Oyedeji (2017) stated that, as they grow older learning, especially in learning measurement concepts, becomes associated with drudgery instead of delight, because of change, of the language used in Mathematics. Mathematics language has a major influence on pupil's attitudes while learning measurement concepts. The problems created by the language used in textbooks, especially at the primary school level, the language of Mathematics learnt in school is far removed from their everyday language, and hence affecting pupil's attitude towards the subject (Sarabi &Abdul, 2017). Sanchal and Sharma, 2017 stated that teachers can do many things to teach measurement concepts to alleviate a pupil's engagement level and confidence in learning measurement (Attard, 2012; Kele & Sharma, 2014).

When pupils first go to school they usually have positive attitudes towards Mathematics. However, as they progress, their attitudes become less positive and frequently become negative at secondary school. Pupils from the ages of 9 to 16 years (although there was a slight increase for 17-year olds), pupils overall intrinsic motivation for academic learning declined, with particularly marked decreases in Mathematics. At this stage, pupils need a driving force that will compel them to develop a positive attitude toward the learning of measurement concepts. Motivation is the driving force that compels or reinforces an action toward a desired goal (Oyedeji, 2017).

According to (Oyedeji, 2017), learning environments at home, at school, and within the peer group accounted for a significant amount of variance in pupil's attitudes and that class ethos had a significant impact on the scores achieved by pupils for these attitudes. Mata, Monteiro & Peixoto (2012) identified three groups of factors that play a vital role in influencing pupils attitudes: factors associated with the pupils themselves (e.g., mathematical achievement, anxiety, and experiences at learning environment); factors associated with the learning environment, teacher, and teaching (e.g., teaching materials, classroom management, teacher knowledge, attitudes towards learning measurement concepts, guidance, beliefs); finally factors from the home environment and society (e.g., educational background, parental expectations) (Mata, Monteiro & Peixoto 2012).

Attard, (2012); Grootenboer, Lomas and Ingram (2008); Mata, Monteiro, and Peixoto, (2012) have identified important factors that contribute to pupil's attitudes towards learning measurement concepts. These include the pupils themselves, the school, the teachers' beliefs and attitudes, learning materials and their teaching methods. Pupil's attitude toward measurement topics is seen as the pattern of beliefs and emotional dispositions associated with measurement topics. It is the positive or negative degree of affection towards the subject of Mathematics. What pupils believe about measurement topics influences what they are willing to say publicly, what questions they are likely to pose, what risks they are willing to take, and what connections they make to their lives outside the classroom. Attitude entails confidence and engagement. How pupils feel about measurement topics is an outcome that is heavily dependent on the local culture and context, age and stage. Mathematics confidence is a measure of pupil's personal belief in their ability to handle learning situations in Mathematics effectively, overcoming difficulties. Mathematics confidence affects pupil's willingness to take on challenging tasks and to make an effort and persist in tackling them (Iji, Abah & Anyor, 2017)

Studies conducted by Dickinson and Hough (2012); Kacerja (2012); Ivee (2018) identified that teaching measurement concept in real-life contexts and using appropriate teaching materials enhances pupil's enjoyment of measurement lessons. The relationship formed between the pupils and the task fosters a pupil's engagement in the measurement tasks. By creating, exploring and verifying mathematical ideas pupils tend to see the importance of learning measurement. Sanchal and Sharma (2017) indicated that pupils who were taught traditionally viewed measurement concepts as a collection of procedures. In contrast, those pupils who were taught in a context viewed measurement concepts as an active and inquiry-based discipline. Dickinson and Hough (2012) worked on a project that trailed teaching measurement in a context. The project included the views of both teachers and pupils on the impact of teaching measurement in a context (Sanchal & Sharma, 2017).

There is a need for teachers to find ways to encourage the pupil's engagement and confidence in learning measurement concepts. This can be achieved by implementing meaningful activities embedded in real-life contexts (Sanchal & Sharma, 2017)

## Research Objectives

The main aim of this study was to find out the various attitudes experienced by learners in the middle-upper primary, while learning Measurement concepts in Ndii-ini primary schools in Ruiru sub-county, Kiambu County, Kenya.

## Methodology

The purpose of this study was to examine the various attitudes experienced by pupils in the middle-upper primary while learning Mathematics concepts in Ndii-ini primary school. Specifically, this research focused on pupil's attitudes towards Measurement concepts. The study used simple random sampling in selecting thirty (30) pupils, who were observed and interviewed on how they learned measurement concepts. Data were analyzed by the research objective. A reliability test was done using Cronbach alpha. Cronbach alpha coefficient was used to measure the consistency of the pupil's attitudes towards learning measurement concepts.

## Results of the findings

The finding of the study revealed several factors contributed to the negative attitude of pupils towards learning Mathematics, Mathematics language was the main factor, lack of learning materials and absenteeism that contributed to pupil's low performance. The main cause of absenteeism was due to high poverty levels in the areas. The study indicated that the issue of language barrier needs to be addressed with a lot of seriousness. Mathematics language has a major influence on pupil's attitudes (Sarabi & Abdul, 2017). Most pupils did not understand Mathematics terms used they got mixed up when the Mathematics language changed i.e. sum as addition product as multiplication. Teachers simplifying Mathematics terms such as therefore with what about. Also, the English language was a barrier since most pupils use Kiswahili as a medium of communication at school and vernacular at home, language lowers comprehension skills.

From the finding many pupils believed that Mathematics was a complicated subject and that why here was low performance. Many pupils believe that Mathematics is for geniuses. Mata, Monteiro, and Peixoto, (2012) identified factors associated with the learning environment, teacher, and teaching (e.g., teaching materials, classroom management, teacher knowledge, attitudes towards learning measurement concepts, guidance). Lack of learning material, to motivate pupils learning was also a factor, where most of the books were torn, loss of books due to transfers, whereby pupils would go to unknown areas and pupils dropping out of school due to many factors. This makes it difficult for teachers to be able to give pupils extra work for revision. Most of the blackboards were in a poor state, pupils strain to see the workings on the blackboards.

Most teachers don't prefer to teach the subject, their negative attitude also affected pupil behavior entry in every examination that they did. Sanchal and Sharma (2017) suggested that measurement concepts should be taught in context. However, most pupils stated the use of technology boosted their confidence in learning and it also made learning more interesting.

## Conclusion

The study found that were not teachers were not adequately in-serviced, to teach Competency-Based curriculum. The study concluded that pre-service teachers should also be trained to reinforce the use of Competency-Based curriculum. It also concluded that the government of Kenya to provide CBC training to pre-service teachers, instead of focusing on in-service teachers. Organize seminars and workshops for teachers regularly and involve parents to boost pupil's attitudes towards the subject.

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