SCIENCE TEACHING IN AFRICA: ENHANCING AND SUSTAINING TEACHER EFFICACY

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ABSTRACT

Given the well-established need for teacher intervention in Science learning, it is now time for closer attention to be given to research on teachers and teaching in schools, so as to address the question of quality Science education locally (in Africa) and internationally. In this paper I argue that Science teacher efficacy is a key issue and a major factor in successful implementation of effective Science education in Africa. It presents the Kenyan case as a typical African scenario. Located in the sub-Saharan region, Kenya shares similar national development plans and dreams as well as socio-economic conditions with most African countries. In this report, the current status of Science education in Kenya is explained, and a blueprint for how to enhance and sustain effective teaching of school Science, likely relevant to any country in Africa, is presented. This work argues that teachers' use of contextual and practical approaches would enhance the efficacy of school Science teaching. The aim of this paper, though focusing on a Kenyan context, is to generate debate about Science education in Africa, as well as expose issues for cross-border research on teachers and the teaching of Science.

Key words: teachers, teaching, Physics, Science education, Africa, Kenya, efficacy

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INTRODUCTION

The aim of this paper, though focusing on a Kenyan context, is to generate debate about Science education in Africa, as well as expose issues for cross-border research on teachers and the teaching of Science. As a background to the particular focus on teachers, the paper refers to the old argument by Schwille et al. (1983) that has highlighted the central role or power of the teacher in the teaching process. This argument is stated as follows:

> Teachers, as they interact with students, are the ultimate arbiters of what is taught (and how). They make decisions about how much time to allocate to a particular school subject, what topics to cover, when and in what order, to what standards of achievement, and to which students. Collectively, these decisions and their implementation define the content of instruction (Schwille et al., 1983: 3).

What is evident in this argument is the fact that teachers, especially the way that they plan and go about their teaching duties, can profoundly impact student learning and outcomes (Ngware, Oketch & Mutisya, 2014). Drawing on this key role of the teacher, this paper particularly foregrounds the quality of Science teaching at secondary school level as the single most important factor of the overall success of any Science education curriculum. This is in line with the argument that the success of a formal Science education curriculum is dependent on the quality and performance of Science teachers across the school levels (Allais, 2014; George, 1999 & 2000; Monteiro, 2015). This in effect suggests that successful Science education depends unequivocally on how effectively Science teachers educate students in Science knowledge, skills, and dispositions. The relevant faces of successful Science education and the relevant perspectives on effective Science teachers' practices are incorporated along the way. The discussion that follows presents the Kenyan Science education situation as a typical example of the prevalent situation in Africa, and suggests a way forward.

SCIENCE IN THE KENYAN SCHOOL CURRICULUM

Science is a high-status subject in Kenya because of the many job and training opportunities available to graduates in Science-related professions. Its high status has also been achieved due to its deliberate promotion by the government as a necessary ingredient towards the realisation of a fully industrialised economy

(Oyoo, 2010; Republic of Kenya, 1998). Science education, as currently conceived, arguably started in Kenya after independence in 1963, since formal education was not widely available in Kenya prior to independence. The system of education in Kenya prior to independence was discriminatory and fell exclusively in the domain of a minority non-indigenous population. Due to the non-universal, non-compulsory nature of formal education at the time, a very small number of privileged indigenous students attended school. Access to Science is therefore relatively new in the national school curriculum. Apart from the discriminatory school education inherited at the time of the country's independence, teaching approaches then in use best fitted what could be termed a 'cookbook' approach to the teaching of Science (Ogunniyi, 1986; Swift, 1983). The Science syllabus was of the 'traditional' variety: students were taught the basic principles of Science and good thinking skills through standard topics and experiments. The main aim was to prepare youths for further studies in Science, but it was also hoped that they would be able to apply the skills that they learned in Science in everyday situations. The fact that this primary aim remained the same even when the first post-independence system of education (Republic of Kenya, 1964-65) changed to the current one, the 8-4-4 system of education, means that successful Science education is Science education that can enable the achievement of this primary aim. The current system of education is named 8-4-4 because learners attend eight years of primary school and four years of secondary school, and those who are selected to join universities take at least four years to complete an undergraduate degree at any of the Kenyan universities (Bogonko, 1992; Republic of Kenya, 1981; Wasanga & Somerset, 2013; Wosyanju, 2009).

At inception of the current 8-4-4 system of education in 1985, its good feature was the fact that it allowed all school children a chance to learn Science as a compulsory subject, using a common syllabus for the first 12 years of schooling; that is, from the primary school level right to the end of secondary education. In the primary schools, the subject was, and still is, taught as a single subject called Science, while the secondary school level Science is divided into and taught as three distinct subjects: Biology, Chemistry and Physics (Republic of Kenya, 2002). The syllabi were designed to make each subject 'interesting, real and more meaningful to the learner through the emphasis on the application of knowledge gained to the local environment'. Furthermore, 'project work in the syllabus was intended to create a new dimension in application of knowledge gained and to add more interest and fun to the subject' (Republic of Kenya, 1992: 25). Also included in the Science syllabi were issues regarding how Science impinges on society, as the following general aims of the Physics course illustrate:

- To help the learner discover and understand the order of the physical environment
- To make the learner aware of the effect of scientific knowledge in everyday life through application to the management and conservation of the environment, the utilisation of resources and production of goods
- To enable the learner to appreciate the responsibility of the scientist to the society
- To inculcate in the learner a willingness to co-operate in using scientific knowledge in the society (Republic of Kenya, 1992: 75)

While the overall intention of Science education as illustrated above includes the important aim to enhance learners' understanding of the environment, the achievement of this initial intention has remained elusive. The implementation of the Science curriculum has never achieved this aim. The secondary school Science curriculum has therefore had to undergo a number of adjustments and revisions in order to more readily achieve its objectives.

Science subjects were previously offered either as three separate subjects (Biology, Chemistry, and Physics) or as two subjects: Biological Science and Physical Science. It was expected that only the schools with well stocked laboratories (mainly the national and provincial/county schools) were to offer the three Science subjects separately in Forms 3 and 4. Although Physical Science as a subject has since been phased out, Biological Science, instead of Biology, is still offered to students with disabilities, perhaps because of the nature of the practical examination in Biology. Other students without disabilities are now expected to select at least two Science subjects from Physics, Chemistry and Biology. Since Chemistry has been made compulsory in most schools, students are expected to choose between Physics and Biology as their other secondary school Science subject. Many students therefore take Chemistry and Physics or Chemistry and Biology examinations at the end of secondary school in order to be granted the Kenya Certificate of Secondary Education (KCSE), which is equivalent to other countries' university entrance examinations. A small number of students in a small number of schools register for Physics and Biology. Some students take all three (pure) Science subjects, although these are mostly youths from secondary schools with better equipped laboratories.

In spite of the changes to the Science curriculum thus far discussed, the secondary school Science curriculum continues to be broad and overloaded. A survey of the revised Science education curriculum currently being used in schools reveals that the order of the topics and the clearer definition of the specific objectives are the only things that may have been revised (see Republic of Kenya, 1992 & 2002). The teaching requirements in particular therefore remain the same, and similar demands are placed on relatively underdeveloped infrastructure in the less endowed schools, mainly from the rural and poorer regions of the country (Development Policy Management Forum [DPMF], 2012). With the introduction of pure Sciences in all secondary schools, changes now need to be made to allow for the teaching of separate Science subjects in all secondary schools. Yet, all along, this has not been affordable in the less endowed schools. This seems to suggest that Science education in these secondary schools could be heading toward more problems, and by extension, Science education in the country will continue to be challenged because most schools lack the materials and resources to enact the mandated curriculum objectives.

Furthermore, the many curriculum reforms, like the recent phasing out of the Physical and Biological Sciences, have resulted in making 'whole' Science available to fewer students in secondary schools. The consequence of this has been that the students in the less endowed secondary schools have been disadvantaged further, since their access to Science has now been reduced. While this might resurrect the question of what the aims of Science education in Kenya need to be, it also suggests that reconsideration be given to the government's plan to industrialise the economy by the year 2030 (National Economic and Social Council of Kenya [NESC], 2007; Wosyanju, 2009) through generating a qualified and scientifically literate human workforce. Curriculum changes may work against the development of Science education in the country: the curriculum reforms thus far may hinder both the intended wider access to Science education and the success of the plans to industrialise the economy.

Apart from the challenges that curriculum changes have posed on the attainment of the aims of Science education in Kenya, Science education has also faced other problems and challenges, some being a consequence of the government's policy of cost sharing, as will now be discussed.

PROBLEMS AND CHALLENGES

The Kenyan government's policy of cost sharing in education has been a major stumbling block to the success of education in the country generally (Mulongo, 2013; Mungai, 2012). Under this policy parents have been left to meet most of the costs of secondary schools, which include general maintenance, physical facilities development, vehicles, electricity, water and other services, as well as personal reimbursement of support staff (Sifuna, 2005; Republic of Kenya, 1999). The high level of unemployment in the society overall and the absence of any social security arrangements have rendered most parents unable to share costs (UNESCO, 2004). This is despite the fact that the government has since reduced the amount of school fees paid by parents for the secondary school education of their children (Jagero, Ayodo & Agak, 2011; Ohba, 2011). The amount of the government subsidy for secondary-school fees is such that the main governmental responsibility is still largely that of provision of teachers' salaries through the Teachers Service Commission (TSC). The salaries account for 90% of the expenditure (Mulongo, 2013; Odhiambo, 2003 & 2004; Sifuna, 2005). The government is still unable to provide all the basic infrastructure for learning and teaching; this therefore remains grossly inadequate in many primary and secondary schools. The Science subjects, because of their capital-intensive nature, remain the hardest hit in this respect. This is so even with additional funding being made available through the Constituency Development Fund (CDF) managed by the members of the legislative assemblies for the constituencies (Nyamori, 2009).

In many secondary schools, for example, Science laboratories, workshops and equipment are inadequate and curriculum materials such as textbooks are in short supply. The situation is so serious in the poorer regions of Kenya as to make it safe to claim that, apart from the enrolled students, such schools lack everything else needed for the successful learning of Science (DPMF, 2012; Ojwang, 2004; Sifuna, 2007). Furthermore, in many schools the number of students in a classroom is higher than a teacher can effectively handle; in some schools, a stream has as many as 65 students (Sifuna, 2005). As a result of this, giving individual attention to students is not possible.

While there is a chronic shortage of teachers for Science subjects resulting in very heavy teaching loads for the teachers who can teach these subjects, the shortage of Science teachers has been aggravated by the government's freeze on mass employment of teachers, which has been in force since 1997 (Kwayera, 2011;

Thuranira, 2010). All teachers at secondary level are supposed to have two teaching subjects, and the rule that expects all students to register for at least two of the three Science subjects (with an option between Physics and Biology) is an apparent attempt to reduce the large teaching loads for the existing Physics teachers. This would seem to be supported by the phasing out of Physical Science in all schools and Biological Science in some, because some teachers have been teaching both of their Science content areas to large classes.

The need for better leadership in secondary schools is rarely mentioned, although many Science teachers have talked about school principals who are deliberately not interested in the Science disciplines (Mwangi, 2009). In the lived experience of this author, some school principals have often frustrated Science teachers' efforts to improve the learning of Science subject matter in secondary schools (Oyoo, 2004). While some principals have openly discouraged students from registering in certain subjects, notably Physics, others have deliberately avoided acquiring even the most basic scientific equipment. This is despite the fact that parents have had to pay for the purchase of scientific equipment and chemicals as part of the cost sharing of education. In some schools, lack of apparatus and materials for Science teaching has apparently been due to the diverting of funds by school principals (Kigotho, 2004). This may be due to the amount of money used in extra-curricular activities such as drama and sport, in relation to the amount of money put aside for these activities in the annual fee structures. This apparent diversion of funds may be the reason that often, no money is allocated to activities related to Science learning, such as students' participation in Science conferences and fairs, or even trips and study excursions.

The overall annual outcomes in each of the Science subjects at the end of the secondary school examinations in Kenya has generally been low. The highest mean score ever attained in each of the subjects in the KCSE since its inception in 1989 confirms that on average, quality scores have always eluded Kenyan Science candidates. An analysis of the levels of attainment in the KCSE covering the period 1989 to 2006 (inclusive) as in Table 1 reveals that in none of the three tested Science areas has the overall mean score ever reached the 50% mark in any one year. Although Table 1 presents an analysis based on the statistics for the period 1989 to 2006 (inclusive), a more recent analysis of the situation (Musasia, Abacha & Biyoyo, 2012) has indicated that this low level of performance in the Science subjects is still prevalent in Kenya.

Table 1: Highest KCSE mean scores between 1989 and 2006 (inclusive)

Subject	Biology		Chemistry		Physics	
GENDER	Female	Male	Female	Male	Female	Male
HMS* %	30.07	33.64	22.31	26.76	38.81	40.57
YEAR	1994	1996	1992	2006	2006	2006

**HMS – Highest Mean Score.* Source: Oyoo (2008: 274)

In spite of these consistently low Science outcomes, there has been an apparent bias on the part of the Ministry of Education and the Kenya National Examinations Council to highlight only the relatively lower outcomes of females, in comparison to the outcomes of males, as the only problem that needs to be addressed (Chetcuti & Kioko, 2012; Sifuna, 2006). The gravely low mean scores on the National Examinations highlight the need to generally enhance student outcomes in the Science subjects. How to improve the level of outcomes in Science is a perplexing challenge to education stakeholders in Kenya. Generally the fault has been attributed to students' and teachers' negative attitudes towards Science. Teachers in particular have borne the brunt of the blame and a review of the current teaching carried out in Kenyan secondary school classrooms may reveal why.

TEACHING OF SCIENCE IN KENYAN SECONDARY SCHOOLS – A REVIEW

Research studies focusing on Science education in Kenya and Africa have been scanty. Consequently, efficacy of pedagogical practices in the teaching of Science in Kenya and Africa has been considered against findings in research conducted mainly in the developed world, regardless of the different contexts. In a review of Science education research, Harlen (1999) has revealed themes that have dominated research in Science teaching to include: use of practical work, taking into account students' alternative conceptions, emphasis on meta-cognition, relating assessment to content, proper lesson planning, strategic questioning, ability of the teacher to display knowledge of subject matter, and use of theories of learning and teaching Science. In the paragraphs that now follow, a review of the teaching that goes on in Kenyan schools is conducted using some of the themes that have dominated international research on effective Science teaching as the lenses to highlight what kind of Science teaching goes on in Science classrooms in Kenya.

Teachers' inability to relate Science to students' real-life situations

In the current Science teaching context, Science teachers have been criticised for not being intuitive and innovative enough in their teaching. Many Science lessons are still chalk-and-talk lectures, in some cases, straight out of the textbooks. The representation of Science in the mainly imported course books has also not been of help to the teachers. Mostly, teachers have aimed at teaching the content as represented in these textbooks, an approach that has not been beneficial to the students' understanding of Science, especially with regard to relating it to their immediate environments. To corroborate this with respect to school Physics, the following is a common comment from Kenyan youths, including current as well as former school students:

> Physics is not applicable anywhere in my life. I would just be swinging pendulums in class but would not see where it could help me. It is never made applicable in our lives and it just looks like something meant for the classroom (Oyoo, 2004: 28).

This has partly been because getting students to pass the mandated examinations is always foremost in the minds of the teachers, and priority is always given to completing the (wide) syllabus. Examples of bad or unfavourable teaching practices are still common. Students' experiences in some Science classrooms still bear characteristics of what was typical in the immediate post-colonial years as described by Museveni (1997):

> In some Science subjects like Chemistry, the teachers would teach badly, introducing new subjects without explaining their genesis and expecting pupils to 'cram' things without understanding them. They would say: 'The symbol for sodium is 'Na'. When I asked 'Why not say 'So' if it is sodium?' they replied: 'You must just take it as it is'. It was only later that I came to learn that symbols were taken from Latin and were internationally recognised. It was really incredible the way some teachers were turning children against their studies, and so unnecessarily. Their attitude was: 'If you want to pass your exam and get a good job, you take it as it is and memorise it' (Museveni, 1997: 12).

This account also illustrates the authoritative nature of some Science teaching approaches, which may be traced to poor preparation of lessons and/or a poor grasp of subject matter by some of the teachers. Lack of knowledge of content, and perhaps the consequence of experiences during their own schooling (similar to Museveni's experience as just described), may be part of the reason many teachers do not teach in ways that relate scientific content to students' physical and social environments. This implies that the teaching approaches being used in some schools are not geared to demystifying Science. In some instances, teaching has served to perpetuate the view of Science as a mysterious thing to students. This claim is based on this author's experience, documented in Oyoo (2004: 28) but reproduced immediately below, with a secondary school teacher of Chemistry during an introductory lesson in Organic Chemistry:

> On teaching us the properties of the element *Carbon*, the teacher stated that 'Carbon can form a chain' and perhaps to help us visualise how long the carbon chain could be, this teacher said that 'carbon can join to carbon, to carbon, to carbon, to carbon, to carbon… up to *Siri Guru Masawa. Siri Guru Masawa* is a place beyond the horizon, usually formed by the red rays of the sun as it sets over … a very large water mass near my rural home. It is alleged (as a local myth) that beyond the horizon, at *Siri Guru Masawa*, wild animals, in fact man-eaters, live. To have to imagine that carbon can form chains up to such a place made me wonder about carbon. In the process I stopped writing but I was forced to write all words including *Siri Guru Masawa* – in my mind, *Siri Guru Masawa* was not Chemistry, yet this teacher did not welcome any questions about this at all (Oyoo, 2004: 28).

Another example of a teaching approach lacking in sensitivity toward Science learners and their backgrounds is evident in the following student's comment about a Physics teacher at a top secondary school in Kenya:

> Sometimes he does something on the blackboard and we just wonder what he is doing... Like working out a question he just speaks to himself... We do very few practical examples and we think he could plan more for us... We are given questions by the teacher and when we look at them and we find that they are too hard and we ask the teacher for help, he does not help (Oyoo, 2004: 235).

Similar findings have been reported in a study that covered both primary and secondary schools (Sifuna & Kaime, 2007: 121) from across the country.

Use of practical work in teaching Science

In many Kenyan schools, including even some secondary schools with ample resources, fully-fledged practical approaches to teaching Science are not a common feature; many teachers do very few Science demonstrations and almost no classroom experiments (Sifuna & Kaime, 2007). It is common in many schools for practical work sessions to be held just before the national examination, particularly once the schools are aware of which apparatus the candidates would be expected to use in the practical exam; this practice still persists across the country (Mabatuk, 2014). Some teachers do not engage in hands-on work because they consider some chemicals as harmful to students' health. This lack of practical work during the teaching of Science means that school Science graduates never attain a mastery of the skills necessary in the learning of Science.

Gender issues in teaching Science

Some teachers still hold to the belief that students' Science learning abilities are determined by their gender (Chege & Sifuna, 2006; Tsuma, 1998). Hence, teachers have been blamed for discouraging girls:

> … by consciously or unconsciously perpetuating long-held myths about girls' inability to cope with these subjects which are deemed more suitable to males. Many teachers discourage girls from continuing with Science… by accepting mediocre performance by the girls as opposed to boys… enforcing the belief that the subjects are designed for boys (Oyoo, 2004: 29).

In one study in the Kenyan context (Oyoo, 2007a) a girl-favourable approach (though not an exclusively girl-specific approach) to the teaching of Physics has been characterised. With this approach, teachers need to attend more to students' social needs in Physics/Science classrooms during teaching. This is the way that has been associated with the 'feminisation' of Science by many Physics teachers (Baram-Tsabari & Yarden, 2008; Chege & Sifuna, 2006; Chetcuti & Kioko, 2012; Sifuna, 2006). Meanwhile, Physics teaching methods in boys-only classrooms have been markedly different. A typical approach is evident in the following statement made by one teacher at a well-established boys-only secondary school:

> It should be known that Physics is a doing subject and the learner has to do more than the teacher does… In Physics, pupils should be involved more with exercises and practical [activities] (Oyoo, 2004: 230).

Such an opinion is perhaps the result of the belief widely held by Kenyan Physics teachers and the society as a whole: that boys are better able to take responsibility for their learning, including the ability to do things using their own initiative. It is therefore a surprise finding that the academically stronger boys who formed part of the sample in the Oyoo (1999) study gave a higher rating than girls to the 'girl-favourable approach' to Physics education. As reported in the study, 'the boys, more than the girls would prefer a teaching approach where Physics teachers give students notes, motivate students and smile at the students in class' (Oyoo, 1999: 44).

While it is the expectation that teachers should know that even among the boys in the Physics classrooms there are individual differences, it could be inferred that the study revealed neglect of use of the affective domain to enhance teaching Physics to male students. The Physics teachers, as a result, could be argued to be exercising gender bias against the male students just as they have been blamed generally for the alienation of girls.

Insensitivity to linguistic ability of Science learners

English is the language of most school education in Kenya, including secondary education. The non-uniform distribution of educational resources in Kenya (Mulongo, 2013; Thuranira, 2010), including the deployment of English teachers, has resulted in students not attaining the required level of proficiency in English at the end of their primary schooling (Clegg & Afitska, 2011; Wagner, 2014). With regard to the role of the English language in mastery of school subjects, the common observation is that students who score poorly in secondary school examinations tend to be those who had low primary school English scores. Hence, proficiency in English is a major contributor to successful learning of most school subjects (Clegg & Afitska, 2011). This observation has led to the widely held assumption that once the students have attained proficiency in English, they should be able to understand everything taught in the classrooms (Rollnick, 1998 & 2000). Consistently lower outcomes in some school subjects in Kenya, especially the Sciences, have however shed doubt on the validity of such an assumption. Yet even Science teachers have fallen victim to this inaccurate assumption; as a result, they have contributed to making Science not only difficult but also unattractive to school students through their classroom language usage. This is evident in one Kenyan Physics teacher's recollection of how he went through school Physics during his school days:

> The first teacher who taught me Physics in Form One messed up my life. He could not communicate. I think he was a very bad speaker and he would also assume a lot of things; yes, just talk, talk, talk and go and he did not involve us in any communication. We didn't have the chance to talk; that was Year One and Year Two. Year Three I was taught by a lady teacher, who would explain every word of the sentence and very exhaustively and I liked it and even now when I meet her I tell her *mwalimu* (teacher) that was good. So I have had those two extremes. Then I think when I was in 'A' level, I was taught by another teacher who was not very keen on explaining the words. So he talked…superficially but in Form Five I had the interest and I could go looking for the meaning of the words myself (Oyoo, 2004: 219).

In this recollection, it is apparent that the first Physics teacher might have assumed that the students had been well prepared in English at the primary school level. Meanwhile, the second teacher taught in a way that the speaker liked. As for the third instructor, the Physics teacher forgave him, since by Form 5 (A level), the student (now teacher) was able to take responsibility for his learning. The question remains as to when or at what level students are best able to take control of their learning. It seems a benchmark level of proficiency in the instructional language and its relationship to successful learning remains elusive (Oyoo, 2007b).

Evidence that Science teachers' use of language during teaching has the potential to reduce or discourage enrolments in Science classrooms can be construed from the response by the same Kenyan Physics teacher when he was asked the following additional question:

> **Question:** So from that experience would you say that the teacher who did not communicate well almost made you opt out of the subject?
>
> **Response**: Yeah it is true. You know Year [Form] 1 and 2 Physics was compulsory and at Year [Form] 3 it was optional… So, at the time I could think of quitting Physics, the better teacher came (Oyoo, 2007b).

The aforementioned are examples of the unfavourable Science teaching approaches that have persisted throughout Science education in Kenya (see also Sifuna & Kaime, 2007). The existence of approaches considered unfavourable by students in secondary schools is itself enough evidence for seeing Science teachers' work as one reason that students' outcomes in Science have continued to be low, as already discussed. While it would be an inaccurate and unfair representation of the Kenyan Science teaching situation to generalise these claims to all teachers in all secondary schools in the country, the point is that some teachers have continued to perpetuate the reputation of the Science subjects as being very difficult. However, other factors mentioned, such as how schools are endowed with resources for teaching Science, impact teaching methods differently in different schools and must not be ignored. Also noteworthy is the fact that individual differences exist among Science teachers. It can safely be stated that in reality, teaching approaches are never the same between any two teachers and may be expected to vary from teacher to teacher even within the same school following the same local and national teaching policies.

Since most Science teachers in Kenya are relevantly qualified, many factors, some beyond the control of these teachers, can be considered instead. Most of the challenges and problems discussed thus far are direct outcomes of the economic policies put in place by the government, especially that of cost sharing (Jagero, Ayodo & Agak, 2011; Mungai, 2012). So the question may be: what is the best approach to successful Science education in Kenya, given the limitations already discussed? As mentioned, the secondary school teacher holds the key, and strengthening the teacher may be the solution. In this light, teaching practices and activities that could help turn around Kenyan students' outcomes and experiences in Science classrooms will now be discussed. This will be accomplished through focusing on the teaching of school Physics, the most challenging Science subject in all Kenyan secondary schools (Oyoo, 2008).

TOWARDS EFFECTIVE TEACHING OF SCIENCE IN KENYA: SOME SUGGESTIONS

Teaching has been described as a web of alternatives in which students engage with content: sometimes with the teacher, sometimes with each other and sometimes alone (Ronkowski, 1998). This view of teaching fits well with the argument that effective teaching of Science requires multi-pronged approaches (Harlen, 1999; Gunstone & Mitchell, 1997; Leach & Scott, 2000 & 2003) in order to make the subject relevant to the students' immediate environment. Matthews has made this even more apparent in the following standard summary of teachers' attempts to create meaningful learning in Science classrooms:

> … during effective teaching of Science, teachers convey the ideas of Science by trying their best to explain the *concepts* and *operations* clearly, to make use of metaphors, to use demonstrations and practical work to flesh out abstractions, to utilise projects and discussions for involving students in the subject matter (Matthews, 1998: 9).

Thus, in Kenya's case, teacher activities that use approaches that make Science/ Physics more accessible and relate it to everyday life would help make teaching more effective. It is the use of these that will provide proof of effective teaching, especially when benchmarked against the themes that have dominated research on effective teaching (Harlen, 1999), including being cognisant of nature and the role of the language of instruction in learning and assessment (Oyoo, 2004). What will be highlighted next are suggestions that help teachers manoeuvre among formidable curriculum and resource challenges that could otherwise deter them from both successful Science education and effective classroom practice.

Countering the foreignness of Science as presented in textbooks

In order to counter the foreignness of Science as presented in imported textbooks, it would help learners to embrace the subject if teachers *used relevant examples for questions and problems during teaching*. The questions can be related to local developmental topics. Assignments after a lesson can be used to show how the lesson topic relates to real-life situations, and this can be done without taking up any valuable lesson time.

Using the environment in teaching

Another way of encouraging learners to embrace the subject as well as a way to relate the content to the students' immediate environment can be when teachers *use a visit or a familiar item to introduce a topic* – a teacher entering a class with a charcoal stove should certainly arouse some interest, probably more than if using standard equipment (Pearce, 2007). Alternatively, a visit can stimulate learning to the extent that, on balance, time is saved and subsequent lesson time may be made even more efficient. It is for this reason that school principals need to support school visits to Science centres or industries in the schools' neighbourhoods.

Using everyday items for experiments and demonstrations

This is the essence of being innovative in Science teaching, for example by using freshly prepared orange juice as a source of electricity. This suggestion is part of the need to be able to improvise (Ndirangu, Kathuri & Mungai, 2003) as and when necessary, especially because of the general lack of teaching materials for Science, including chemicals. Improvisation needs to be considered to include the use of our environment to enhance teaching (Carelse, 1983; Chiaverina, 2008; Martinuk, Moll & Kotlicki, 2010). In this line of argument, it has been suggested that the teacher should be aware of all potential visual aids in the vicinity (Krieble & Salter, 2008; Swift, 1983). For example, black and white wall and metal surfaces in the sunlight can be used to illustrate heat radiation; desk lids and pencils and rulers are ideal for illustrating 'moment of forces' or torque; sagging of power and telephone lines can explain thermal expansion; etc.

Planning for practical work

Mastery of the skills necessary for the learning of Science includes the students' ability to manipulate different pieces of apparatus that they may need to use during practical lessons. A method of training students in handling apparatus (practical work) while at the same time managing time during practical teaching would be teachers' use of a *circuit approach.* This is where a teacher plans for a number of different short group experiments using different pieces of apparatus within one lesson. This way, it becomes possible for the teacher to cover different practicals or make students use different pieces of apparatus in one session – this approach will also enable effective use of scarce Science teaching resources.

Helping with the school Science Club

Many schools have Science clubs or similar out-of-class groups, often working towards a national Science congress or other inter-school competition. If the topics illustrated are being covered in lessons, they will help the keener students to develop their knowledge of the topic and perhaps save time that could have been used during the normal lessons for an explanation. Some projects that relate directly to the local situation will help relate Science to the students' normal environment, and in the process make them see the connection more vividly. Alternatively, this can be done through a formal project.

Using a project approach

Instead of teaching Science/Physics topic by topic, the subject matter to be taught can be embodied in a practical project, for example, a design study. The project could be introduced through a study visit and the Science/Physics topic introduced as needed. Depending on student performance and involvement, such projects could even replace practical examinations, or internal continuous assessment. At a national level this could also be implemented[1] providing safeguards are taken to restrict the degree of teacher and parent participation in the project.

While the above teacher activities are meant to help the teacher to enhance students' understanding of what is taught, teachers rarely question their own practice; yet such questioning would enable them to better their performance as teachers. Such questioning would include the teacher assessing his or her own lessons.

Following up on or assessing own lessons after teaching is necessary, as this provides a reflection on efficacy of approach as a means to effective learning (Hopp, 2008). This is an aspect of 'professional development' under the action research concept. Action research is conceptualised as the act of teachers systematically recording what they do and how the students respond during the lessons. It is a relatively untapped form of educational research that allows teachers to learn from experience. By keeping these records, 'teachers help to halt epidemics of pedagogical amnesia' (Nafziger, 1998: 72). In practice, since teachers rarely look back on their teaching, it is forgotten year-to-year, with the consequence that the learning that does occur is rarely articulated and shared with others. Reflecting on and documenting experiences during teaching sessions could revolutionise teaching and identify favourable approaches for learners in similar environments. This is especially true in determining the cultural propriety of teaching approaches.

Sensitivity to equity issues in Science teaching as an aspect of effective teaching must not be ignored (McCullough, 2007). Neither can the need for sensitivity within the school's language policy toward students' linguistic capabilities be discounted. With regard to gender in the Kenyan Science learning context, changes in how teachers treat female learners would affect how they respond (Oyoo, 2010). Ultimately, the effective teaching of Science requires that the teacher relate to each

1 It is noted that the implementation of this approach in primary schools has not been successful, as parents would buy ready-made items which they would present for assessment on the pretext that they were made by their children.

student in the classroom as an individual, who happens to be of a certain gender (Roudebush, 2010). The following assertion by Murphy (1996) is especially relevant to this line of thinking:

> We need to talk in terms of not a pedagogy for girls or boys but a pedagogy being composed of a range of strategies (which include a range of materials and content, teaching styles, and classroom arrangements/rules) for different groups of students … The key issue is for the teacher to understand which strategy is appropriate and effective in which setting and for which group of students and individuals (Murphy, 1996: 8).

With regard to the language difficulties students may encounter due to inadequate instruction, it might be necessary for teachers to respond to the students' circumstances by lowering the classroom language level (Henderson & Wellington, 1998) so that it does not become a barrier to the learning of Science (Bautista, 2014). This can be done by adjusting for how meanings change when words are used in a scientific context or as scientific terms (Oyoo, 2012). Teachers need to be conscious of learners' proficiency levels in the language of learning and teaching.

In sum, the use of a contextually relevant approach to teaching Science is necessary, especially when Science is taught to learners whose environment is different from what is taken to be conventional (or mainstream) by the scientific community, and reflected in textbooks or research contexts. An effective teaching method involves the judicious implementation of the widely recommended approach to Science teaching: connecting concepts to students' personal, social and physical environments. It is probable that this approach to teaching will demystify Science. Now we turn to the next consideration: How may this approach be sustained?

SUSTAINING EFFECTIVE TEACHING OF SCIENCE IN SCHOOLS: TEACHER AND PROCESS

The central role of secondary school teachers

The central role of Science at secondary school level as the key to the overall success of Science education is first discussed in some detail. The many challenges and problems facing Science education in Kenya, which have been touched on earlier, hinge on policies that the government or other interested stakeholders can work to remove from the schooling system. However, the success of any changes will depend of the quality of the teachers and teaching of Science in schools (Ngware, Oketch & Mutisya, 2014; Schwille et al., 1983). The problem of poor performance in Science education at secondary school level can be traced to the primary school level, where a good foundation in Science needs to be laid. In the Kenyan system (which is similar to many other countries) there is a generalist or non-specialist approach for preparing teachers to teach in primary schools.

At the primary teachers' colleges in Kenya, teachers study 13 compulsory subjects without specialisation in any of them. It can be argued that many graduates of teacher education programmes often leave college without adequate mastery of either the content or relevant methodology required for teaching Science. Many of them are therefore challenged when it comes to laying the necessary foundation in Science for learners at primary school level. However, they cannot be blamed them for this; the entry requirements for Kenyan primary teacher training colleges do not emphasise Science (Chege & Sifuna, 2006). Thus, many teacher trainees who possess a poor background in Science subject matter have gained admission into teacher training colleges. A long-term solution to this problem may be found in secondary school teaching of Science.

In Kenya's 8-4-4 system of education, secondary school graduates at Form 4 are recruited to be educated as teachers of Science at all levels depending on their overall examination outcomes (KCSE). How effectively the secondary school Science teachers teach Science to the secondary school students determines to a certain extent the level of competence of secondary school graduates, who themselves are potential Science teacher trainees. The secondary school graduates recruited to the primary teacher training colleges, as well as those who will join the diploma colleges and universities to be trained as secondary school Science teachers, need to have a good grounding in Science. Currently, these candidates have to pass Science subjects and Mathematics as prerequisites in order to be accepted into teacher training institutions.

The secondary school Science teachers, by teaching Science effectively, will provide a solid foundation on which tertiary educators can build, to produce better and more confident teachers of Science for the Kenyan school system. The quality and efficacy of Science teachers at secondary school level therefore remains the major factor in moving successful Science education forward in Kenya. The processes required to sustain suggested approaches to enhanced practice of Science teaching at the secondary school level are discussed next.

The processes necessary to sustain the suggested teaching approaches

The themes that have dominated research in Science teaching as reviewed in Harlen (1999) have been mentioned in this discussion. Even though the research studies have been conducted mainly in the Organisation for Economic Co-operation and Development (OECD) countries, the findings within these same research themes have always informed pedagogical practices in the teaching of Science in Kenya. Investigating the findings of these research studies has been problematic in that the dissemination of the findings has often occurred without any attempts to localise them to fit the African milieu, which differs from the 'mainstream' Science education terrain. A dire need exists to interpret findings and recommendations from these studies to suit the circumstances prevalent in Africa; some, though understandably not all, of these circumstances have been mapped in this work.

Since field-based research on teachers and teaching in Africa is sparse, this necessitates the raw consumption of findings arising from studies conducted in other contexts. Perhaps the time has come for more *collaborative forms of research aimed at connecting what is known in research terms to the African situation.* Possibly through theory, practice and policy fruitfully informing one another, a means to enhancing teacher efficacy and more successful Science education in Africa will be discovered. Locally, this would begin with wider access to quality Science education, and resources that would promote rather than hinder its success. A further recommendation would be to make 'whole' Science once again compulsory for all at the secondary school level, either with learners taking all the three Science subjects separately or combined under the Biological Science and Physical Science focus areas. The foregoing has arguably justified the potential contribution of *(collaborative) research and curriculum review for sustainable effective teacher practice in Science education.*

Initial and continuing professional development of Science teachers is also a means to ensure and sustain teacher efficacy: appropriate curricula in higher education would aid in the preparation of relevantly qualified and experienced teacher educators over the long term (Creemers, Kyriakides & Antoniou, 2013; Guskey, 2002). Where in-service training or continuing professional development programmes are concerned, foci need be on the weak areas as contextually determined in order to respond to the needs of the local milieu. Calloids, Gottelmann-Duret and Lewin (1997: 125) have outlined the following approaches to in-service education:

- In-service days where teachers are gathered locally at special centres to discuss particular topics
- Short in-service courses lasting up to a week, in regional centres run by national staff members
- Longer in-service courses lasting three months or more, associated with certification and upgrading of qualifications
- School-based in-service support (otherwise known as on-service) during and after school hours, located in schools (see also Sifuna & Kaime, 2007)

Since the financing of education in Kenya is such that funds for these in-service courses are the responsibility of the parents, it is important to consider the most economical approach (Sifuna & Kaime, 2007). It may be true that the cheapest forms of in-service support are almost certainly those which are delivered locally or through school-based sessions, and these can be conducted by local amateurs such as subject associations and panels (Calloids, Gottelmann-Duret & Lewin, 1997; Guskey, 2002). However, the most economical approach and the most lasting approach may constitute two different approaches used in combination.

CONCLUSION AND WAY FORWARD

This paper has revealed that Kenya, along with other African countries (see Ogunniyi, 1986 and Reddy, 1998 for detailed reviews), experiences problems that hinder proper access to and outcomes in Science education. These include, but are not limited to, lack of resources for teaching Science, inadequate laboratory facilities, too few Science teachers and large classes. An additional factor is the remuneration of school teachers, which has been a major source of teachers' dissatisfaction with their work (Sifuna & Kaime, 2007). Hence, it also is an important consideration in the shaping of teachers' general commitment to and satisfaction with their jobs. As is apparent from the discussion in this paper, the scenario in the Science education field in Kenya has been adversely impacted by the government's economic policies. Paradoxically, the government hopes to improve the country's economy through Science education and training (see Republic of Kenya, 1998) and Science education and training requires more of the nation's resources to improve the economy. The reality is that with or without a good Science curriculum, the country's economic circumstances remain an important factor in the level of success of Science education as well as in the efficacy of Science teachers. Curriculum and resource issues aside, it remains a fact that the cause of consistently poor outcomes in Science as discussed can be traced to Science teachers' classroom and teaching practices at both primary and secondary school levels. Hence, a great deal has been suggested in this work concerning how a teacher as an individual can be helped to improve his or her pedagogical practices to become more effective.

In this paper, I have argued that Science teacher efficacy is a key factor in the successful implementation of effective Science education in Africa. The discussion has centred on Kenya as a typical African country that shares similar national development plans and dreams as well as a socio-economic context with most African countries. In this work, suggestions of contextual and (not so new) practical approaches meant to enhance and sustain Science teacher efficacy have been discussed. It is hoped that this work will generate debate within and about Science education in Africa, to ignite productive cross-border research and other ventures to tackle the whole question of quality Science education in Africa and elsewhere. This work is a clarion call aimed at 'waking up' all stakeholders across all nations to the current state of affairs in Science education.

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