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Curriculum Change in Science Education: The case of Botswana

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Abstract
This paper identifies changes that have occurred in science education in Botswana. The paper indicates that changes in content, objectives, instructional strategies, assessment procedures and teaching materials. Changes in Botswana science curricula were a result of changes in developed countries especially Britain. The changes were also introduced to make Botswana science curricula relevant and meaningful to learners. Benefits such as training technicians, preparing the nation for technology were derived from changes in science curricula. However some changes were not all beneficial to Botswana. There was a lack of teaching materials, science specialists for various science disciplines. In conclusion implications for teaching new curricula were discussed.
Keywords: Curriculum change, Science Education, Botswana

Introduction

Many science curriculum projects mushroomed in developed countries after the launching of Sputnik into space by the Russians in 1957 (Martin, et al, 2005). The Russian spaceship caused panic amongst the Western World especially the British and the Americans. The Americans and the British realized that they were behind the Russians in science and technology. This gave an impetus to curriculum reforms in science education in these countries. Drastic changes in science curricula of these countries were introduced as a means to ensure that they are not behind the Russians in technological developments.

In Britain, Nuffield and Scottish Integrated Science Projects (to name a few) were launched into both primary and secondary schools. In the USA, SAPA, SCIS, ESS were launched into primary (elementary) schools while BSCS, PSSC and Chem Study (to name a few) were launched into secondary schools. One common characteristic of both the British and the American Curriculum Science Projects was that they were process oriented. Students were to act and behave like scientists. The British placed more emphasis on secondary science while the Americans placed more emphasis on both elementary and secondary science. The British were of the view that a strong secondary school science curriculum would lay a strong science background for students who want to study science at institutions of higher learning. On the other hand the Americans contended that a strong science background should start at the elementary level of education to enable students in junior secondary schools to study science with confidence and to study science concepts at more advanced levels of education.

Textbooks which were activity-oriented were produced on a large scale and payments for these projects were made by governments (Martin, et al, 2005). The writing of the textbooks followed the observation that sound and lasting learning can only be achieved through active participation (Carin & Sund, 1989)

Changes in the Primary School Science Curriculum

The winds of change that affected Britain also affected its High Commissioner Territory, Botswana. New science curricula such as Nuffield Projects, Scottish Integrated science, etc were implemented in the UK schools in the early nineteen sixties. However, in Botswana science was introduced in primary schools for the first time in 1969 (Rosser and Leburu, 1980). Prior to 1969 Botswana had Nature Study, Physiology and Hygiene, and Health Education as science in its primary school curriculum (Mosothwane, 1995). After obtaining its independence from Britain in 1966, Botswana realized that Nature Study, Physiology and Hygiene, and Health Education did not lay a strong foundation for training its citizens in technically oriented careers and realized that the foundation could only be made if science is taught in primary schools.

Therefore there was a change in content, methodology and teaching materials. With regard to content, physical science concepts such as electricity, magnetism, states of matter, etc. were taught in primary school science. Investigation or discovery methods were recommended as appropriate instructional strategies for teaching primary science. This was a drastic change from the normal exposition which was commonly used in teaching Nature Study, Physiology and Hygiene, and Health Education to investigation which was new to primary school teachers. With regard to teaching materials, there were no prescribed textbooks to help teachers prepare science lessons.

Although changes were introduced in the primary science curriculum, teachers were not ready for them. The main reason being that science was new to them and that they did not undergo any in-service training in it. Furthermore some concepts were well above primary teachers' level of understanding, e.g. Atomic weight (Republic of Botswana, 1969). In addition, teacher training institutions did not have science in their curricula; but only physiology and hygiene. Teaching materials such as textbooks, worksheets, etc. were also not available.

Although there were problems caused by the introduction of science in primary schools, the changes were however, beneficial to Botswana. First graduates from primary schools were trained as technicians in some

fields. This helped Botswana to have technical officers for some very crucial posts of responsibility. Secondly, primary science laid a foundation for further studies at the secondary level of education. Graduates from primary schools did not meet science for the first time when they entered secondary schools; consequently this facilitated the learning of science. In other words the language of science was familiar to first year secondary school students. Changes in science were also introduced in junior secondary schools.

Changes in the Junior Secondary School Curriculum

Although junior secondary schools had science curricula namely Alternatives A and B, their content topics were not relevant to the innovations suggested by the Western countries in response to the launching of Sputnik. As a result, Botswana looked at various science curricula of other countries, but was impressed by both the Caribbean Science and Scottish Integrated science curricula. A science education officer who was by then a British decided on behalf of the science panel to adopt the Scottish Integrated Science Version. His reasons for adopting the Scottish Integrated Science were that it used process skills to teach content and as such pupils will get excited when doing science activities. Science process skills are reported to have promoted children's positive attitudes and interests in learning science (Prophet and Thapa, 1999).Therefore, Scottish integrated Science was introduced into secondary schools in 1974 (Makunga, 1980).

There was a drastic change in teaching methods from that of exposition used in Introductory Science Alternative A to that of investigation in which students used worksheets to record the results of experiments conducted. It was a turning point in the teaching of junior secondary science in Botswana. The philosophy of Scottish Integrated Science Curriculum was that knowledge is holistic but not compartmentalized. There was great excitement about the new science curriculum (Makunga, 1980); however, some problems were encountered in the new curriculum.

First teachers were not trained in teaching science in an integrated manner (Makgothi, 1986). Secondly, secondary school teachers were specialists (Biologists, physicists and chemists), consequently could not effectively teach all the three science areas in an integrated way. Consequently, biologists concentrated on biological concepts, so do chemists and physicists. Thirdly, there was a consistent shortage of some chemicals. As a result some worksheets were left blank as students could not do experiments to complete them.

However, Botswana was fortunate in that it got some expertise from Swaziland which was the first British Territory to introduce Integrated Science in its secondary schools. Botswana, Lesotho and Swaziland were the three British Territories in Southern Africa that used exactly the same science curricula and as a result were always working together whenever a new curriculum or some innovation was introduced in science.

Although problems were encountered in the Scottish Integrated Science Curriculum, benefits also emerged. First, Scottish Integrated Science equipped pupils with Laboratory skills needed for further learning of science in senior secondary schools. Learners were familiar with Lab activities and had the opportunity to learn names of lab equipment. Students were not afraid of handling some equipment. Secondly Scottish Integrated Science helped learners to realize that learning is a process not a product. In other words, any concept covered was followed by experimentation. This is in agreement with Bruner's philosophy of learning. Thirdly, Botswana got expertise from international scholars because its science education officer got the opportunity to interact and to exchange ideas with other scholars. This gave Botswana a reputable international status. Changes were also introduced in senior secondary school science curricula.

Changes in the senior secondary school science curriculum

Botswana had various science curricula at its senior secondary school level of education. These included Health Science, Biology and General Science (physics, chemistry and biology), however, in the late 1960s, physical science, biology, chemistry and physics (pure sciences) were introduced in senior secondary school science curricula as separate subjects. The content topics of physical science were different from that of general science. Human and Social Biology was introduced in 1973 to replace Health Science (Nganunu & Clegg, 1980). The content topics of Human and Social Biology were also different from that of Health Science. Human and Social Biology approached science from both a social and scientific point of view while Health Science approached science from a scientific point of view only.

Senior secondary school science subjects laid a strong foundation for learning science at higher levels of education. The changes that occurred in Botswana science curricula were facilitated by some factors.

Factors which influenced changes in science curriculum

The launching of Sputnik into space was the main factor that contributed to curriculum reforms in science education in the western world. When the Americans and the British changed their science curricula, developing countries too changed their science curricula. But developing countries such as Botswana were influenced by some other factors. These included socio-political status, economic status, the findings of research studies, the status of teacher qualification and the influence the curricula will have on enriching the country's cultures.

Socio-political influence: Developing countries had to see that new science curricula were relevant to their needs

and their education system. Therefore policies that were considered appropriate were put in place. The issue of benefits that society will derive from the new science curriculum was given priority. In the context of Botswana, science was introduced in both primary and secondary schools with a view that a technologically skilled nation will be produced and as such will promote economic developments (Republic of Botswana, 1973).

Botswana realized that it could not improve its industrial and technological developments if it does not produce technologically skilled human power. Botswana was also able to source finance from other countries to pay for science workshops and for in-service training of its teaching staff especially from the Americans and British. This was due to the fact that Botswana was politically stable and its leaders were not corrupt.

Economic status

For a country to introduce new curricula there must be finance to pay for new teaching materials, such as books, worksheets, etc. Furthermore there must be some money to run workshops and to send teachers for in-service training. It therefore means that Botswana was in a better position to introduce new science curricula because it had finance.

Research Studies on the Status of Education:

Before Botswana could introduce a new science curriculum in its primary or secondary schools, research studies were conducted to identify the strengths and weaknesses or loopholes in its education system. Two comprehensive research studies were conducted in Botswana in 1977 and 1993 (Republic of Botswana, 1977 & 1993). Based on the findings of these studies, recommendations were made that had drastic effects on primary and secondary science curricula in Botswana. The findings of these studies reported that primary science was in a deplorable state and was to be changed so that it is relevant and up to date. Furthermore, junior secondary science was reported to be too academic and less relevant to Botswana. Similarly senior secondary school science curricula were found to be strongly tilted towards the British secondary school science curricula. In response to these observations, changes were made.

Based on the findings of the 1993 NCE research study, it was recommended that Environmental Science be introduced in Lower Standards. This was in accordance with the UN suggestion that environmental literacy of the public could be enhanced at a tender or young age. It has been observed that responsible environmental behaviors of children are easily developed at a very tender age, hence the introduction of Environmental Science in Lower Standards. Environmental Science is an integration of three subjects (Science, Home Economics and Agriculture) and it reinforces that idea that when one solves a problem, one does not use one skill, but an integration of skills. Environmental science was based on the school thought called progressivists which purports that knowledge is holistic but not compartmentalized.

Teacher qualification

When Botswana introduced new science curricula, it was satisfied that its teachers were qualified to teach new curricula. Most teachers who were members of science panels were considered competent to teach new science curricula. Research indicates that teachers who possess strong subject matter are capable of not only delivering the subject matter, but also using a variety of teaching strategies to enhance and promote understanding of science concepts (Barnes, 1996). Furthermore, teachers who participate in curriculum development can successfully implement the new curriculum because they feel they own it. It should be noted that teachers who do not participate in curriculum development could retard the implementation process. Teachers are very conservative people, whenever a curriculum is imposed on them, they could easily sabotage and resent it. Teachers want the status quo to remain the same.

Cultural influences

Before a new curriculum is introduced in a country, those who are responsible for that country's educational system consider the effects a new curriculum will have on the culture of the people for which the new curriculum is being developed. For example, some countries do not allow schools to teach children about family life education or sexuality. However, a country such as Botswana has in its science curriculum concepts such as birth control, abortion, HIV/AIDS, etc (Republic of Botswana, 1996). Culturally, Batswana were not used to talking about sexuality to children in the past; however, due to the AIDS pandemic, Batswana accepted that violation of some cultural norms and values could save the nation from the scourge of HIV/ AIDS pandemic. A curriculum worker determines content, activities and the educational environment and his/her task is to enhance culture and values. Culture and values shape children's beliefs and attitudes acceptable to society (Ornstein and Hunkins, 1993).

Psychological influences

Botswana science curricula have been influenced by the work of psychologists, such Piaget, Bruner, Gagne, Ausubel and Vygotsky (Mosothwane, 1995). Piaget and his co-workers revealed the complexity of child development, the rate at which children's thinking processes develop, the unsuitability of abstract work at early stages of cognitive development and the significance of helping children to develop their own cognitive structures (Watson, 1976). On the other hand, Bruner has also acknowledged stages of cognitive development which he says must be considered when teaching to avoid a situation where young children could be given

abstract work which is far beyond their cognitive processes. Bruner is of the view that concepts are in a hierarchy and as such teaching in lower classes should start with the simplest concepts and progresses to the more complex ones, hence a spiral curriculum. Bruner is of the view that children learn better when fully engaged in activities. He is an advocate of discovery teaching. In Botswana, electrical concepts taught in Form I are not the same as the ones taught in Form IV. Gagne is also an advocate of hierarchical knowledge. He asserts that science concepts must be taught in a hierarchy beginning with the simplest and progressing to the more complex ones. Gagne's ideas are used in our science curricula especially primary science. Gagne suggests that concepts should be repeated until children understand them. Our current primary science curriculum is written in modules (units) in which simple concepts are taught first followed by difficult ones.

Ausubel, a constructivist, acknowledges the fact that knowledge is environmentally determined and asserts that children's prior knowledge should be used in teaching science. He opines that if children's preconceptions are used in teaching science, then learning becomes meaningful. Meaningful learning occurs when children are able to link what they are learning with what they have already learned. In his view, teachers should start with what is in children's environment (what children already know) and connect that with what they are just about to learn, hence the justification for an advanced organizer. Vygosky was constructivist and an advocate of co-operative learning. His ideas of working together is reinforced by his famous quotation 'What children can do together today, they can do alone tomorrow'. Our children both in primary and secondary schools should work in groups. This helps those who may not understand some concepts to be helped by others in the group who understand. Contribution in class by all children in the class discussion gives every child an opportunity to talk and to ask questions. Our current primary science curriculum encourages such an approach.

External influences

The launching of Sputnik into space is a case in point. After the launching of Sputnik into space by the Russians, the western countries changed their science curricula to introduce stronger science curricula which laid a strong foundation for science and technology. Science projects which were introduced in Britain were also introduced in its ex-colonies and territories (Mosothwane, 1995). Commonwealth countries send their people to Britain to study and therefore it makes a lot sense to use science curricula similar to that of Britain because their students will be able to study without much difficulty. Furthermore most developing countries send their people to study in the USA; therefore using science curricula similar to those of USA makes a lot of sense because it will facilitate learning.

Subject panels/Curriculum specialists

In Botswana, most members of science panels are also researchers, therefore they are involved in the decision making stage where they will make comments on whether a new curriculum should be introduced and to what extent it will benefit the country. Science panels' comments on a new curriculum are taken seriously by the government. The Revised National Policy on Education of 1994 (Republic of Botswana, 1994) recommended the establishment a National Science Panel to oversee the implementation of science curricula nationwide and to develop science curricula that will help to promote the scientific literacy of Batswana. The panel is comprised of primary, secondary and tertiary science teachers. The contributions made by these different specialists have contributed to the development of coherent and strong science curricula in Botswana.

Textbook authors

Science curricula in Botswana have to a large extent been influenced by textbooks especially well written ones. For example, Junior Certificate Integrated Science was influenced by UNESCO science books. A.F. Abbott physics textbook had an influence on the current Botswana General Certificate of Secondary Education (BGCSE) Physics Syllabus. Abbot Ordinary Level textbook is well written and has good illustrations which help teachers to explain some concepts clearly. Physics panel members were impressed by the way the textbook is written and as such were to ensure that the content topics of the textbook are reflected in their physics syllabus.

The above catalysts of change were not only germane to developing countries, they were universal. In Botswana, changes in the science curricula were considered essential for they bring in new knowledge, strengthen science curricula and make science curricula more relevant and meaningful.

Phases inherent in curriculum innovation

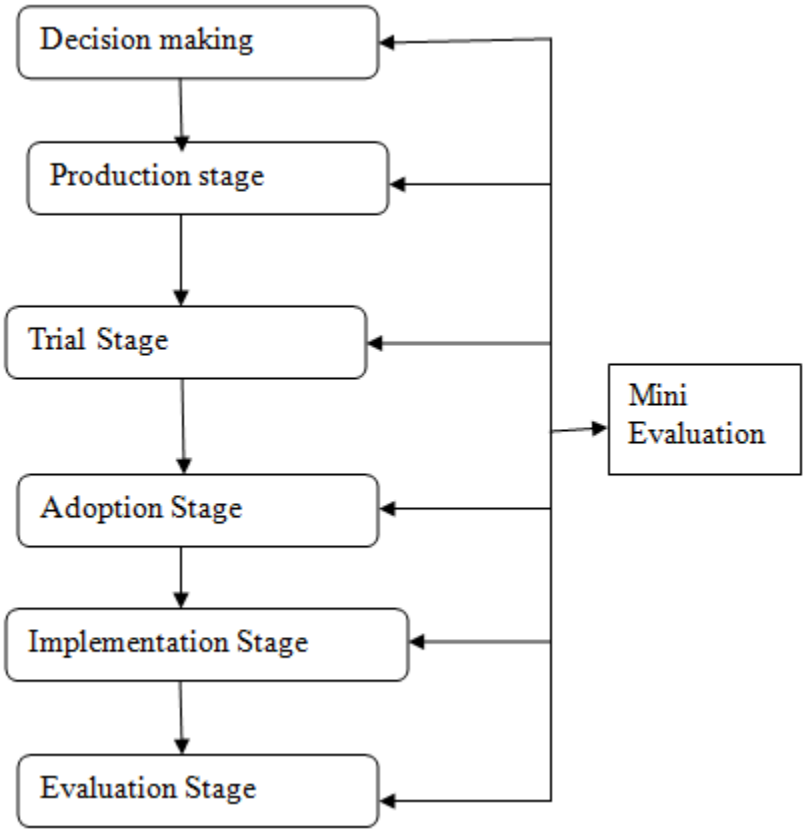
Curriculum development is a process in which steps are followed when a new change is introduced. These steps are referred to as 'phases'. First, who decides to introduce changes? This phase of curriculum innovation is referred to as the *Initial or decision making phase*. The Permanent Secretary in the Ministry of Education and Skills Development will identify the needs for a new curriculum. In the context of Botswana, the Permanent Secretary in the Ministry of Education has the total responsibility to initiate the changes that he/she thinks will benefit the country. The normal procedure is that he/she will inform the Minister of Education of his/her intention and the benefits the country will get from the new science curriculum. If the Minister agrees, the Permanent Secretary (PS) will inform his subordinates (Subject Education Officers). Education officers and the

PS will meet and formulate a course of action. They then decide to adopt the new science curriculum (it may be a curriculum from other countries which they think will benefit Botswana). Objectives, content topics are modified to suit the Botswana situation. Education officers will then call subject panel members to discuss the new curriculum.

After they have agreed on what to include or exclude from the curriculum, materials are then developed (the developmental/ *production phase*). This is the phase or stage in which teaching materials (textbooks, worksheets) are produced .After the production of materials some teachers will trial them in their schools. This phase of curriculum innovation is called the *trial stage/phase.* The essence of the trial phase is to get feedback from schools on quality of the materials. In this phase, teaching materials are improved. The panel will ensure that the materials are in line with the educational goals of Botswana. Teachers who trailed the materials will identify problems encountered during the trial stage and will report them to panel members who will make corrections accordingly. After the corrections have been made, the new curriculum is then disseminated to education officers who will inform schools that a new curriculum will be implemented effective from a given date. After a new curriculum has been disseminated it is then *adopted by school* (the adoption stage). The new science curriculum becomes an official document and it has to be *implemented* (the implementation stage) at the classroom level.

The implementation stage is very critical for it is carried out entirely by teachers some of who are not members of subject panels. Furthermore, this stage is critical because it is here that teachers can sabotage the new curriculum. In this stage, the critical question is 'what strategies should be put in place to facilitate the implementation process? Normally in Botswana, the last stage is *evaluation*. Evaluation is done through the analysis of the results of tests and national examination. This is easiest way to evaluate a new curriculum. However, it should be noted that evaluation is a continuous process which should be done from the developmental stage throughout all stages of curriculum development. In Botswana, two comprehensive evaluation processes were conducted in 1977 and in 1993. These National Studies culminated into two comprehensive reports called The National Commissions on Education (Republic of Botswana, 1977 & 1993). The two comprehensive reports recommended drastic reforms in Education System of Botswana (Republic of Botswana, 1977 & 1993).

A summary of phases inherent in curriculum innovation/development



(Based on Harding, Kelly, &Nicodemus, 1976's ideas).

The current status of science education in primary and secondary schools

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, EFA goals and MDGs.(Vision 2016, EFA, 2006; Republic of Botswana, 1994 & 2004). The Revised National Policy on Education calls for a scientifically literate nation. Furthermore, the policy document calls for a strong primary science curriculum. The policy paper divided primary science into two parts, namely Environmental Science and Upper Primary Science (Republic of Botswana, 1994). Environmental Science is concerned with care and sustenance of the environment. Its main aim is to promote responsible environmental behaviors in children at a tender age.

Research indicates that children's positive attitudes towards the environment and their concern for a quality environment could easily be developed when they are still young (Mosothwane, 2006). Environmental Science is taught from Grade 1 through Grade 4. Upper Primary Science is taught from Grade 5 through Grade 7. Upper Primary Science has rigorous and lays a strong science background for students who aspire to study science at the junior secondary school level of education Both Environmental Science and Upper Primary Science curricula employ process skills in the teaching of content. This is based on an internationally held perspective that process skills promote understanding of science concepts (Prophet & Thapa, 1999).

Vision 2016, Long Term Vision for Botswana calls for a technologically advanced Nation through a quality science programme. The vision contended that science and technology must be emphasized through the education system and recommends that all children at the primary and secondary levels of education must be encouraged to study science.

Girls in particular have been encouraged to study science since they have the same science aptitude like boys. The Vision document gives reasons for a strong science curriculum required for science and technology. Industrial development requires technicians, electricians and environmentalists. The Vision contends 'a strong capacity in the scientific and engineering disciplines will provide crucial long term support for the manufacturing industry' (Vision 2016, p.39) EFA goal No. 6 calls for a quality science education programme for developing countries. One of the reasons why UNESCO calls for a quality science programme for developing countries is that these countries are still far behind developed countries in science and technology, yet they have abundant natural resources which help them to industrialize their countries.

Junior secondary school science is not in separate disciplines (such as biology, chemistry. earth science and physics), it is integrated. This was to ensure that students see the interrelationships between different disciplines. This perspective is based upon the school of thought called progressivists which purports is that knowledge is holistic not compartmentalized as shown by other science curricula. Although junior secondary science is integrated, the absence of earth science concepts is conspicuous. Therefore, there is an urgent need to include more earth science concepts in the junior secondary science curriculum. The junior secondary school science curriculum partly prepares students for the world of work. Students who pass junior secondary school science are able to go enter technical colleges to further their studies. Following the UNESCO philosophy of basic education, government took a step ahead and ensured that education is a right for all children from primary school to senior secondary school level of education. Students no longer stop their education at junior secondary school level of education and proceed to technical colleges; they all proceed to senior secondary school level of education and some go to technical colleges after the completion of their senior secondary school level of education.

Senior secondary school science curriculum is categorized into four forms of science, namely *single science award*, *double science award, pure sciences (biology, chemistry and physics)* and lastly *human and social biology* which has been designed specifically for private candidates (Republic of Botswana, 2000).

Science Single Award is a form of science composed of biology, chemistry and physics. Students are given one grade in the Botswana General Certificate of Secondary Examination. The objectives of the Science Single Award are divided into two types, namely **Core** and Extended. The core objectives are covered by all students while the extended ones are only covered by very able students.

Science Double Award is a form of science composed of physics and chemistry (physical science) and biology. The syllabus is more rigorous than that of the science single award. Students are given two grades (double), one grade for physical science and the other for biology. The objective of science double award are also divided into **core** and extended. Students who cover the extended objectives are of high ability. In the pure sciences, students write three papers and are awarded three grades. Just like in the single and double awards, pure science also have core and extended objectives. The core objectives are covered by all students while the extended ones which are challenging are covered only by vey able students.

Science curricula for primary and secondary schools included Millennium Development Goal Number 7(MDG #7) because they contain concepts on sustainability (Republic of Botswana, 2004). Environmental sustainability is taught across all primary grades and all secondary forms in Botswana. MDG #7 was instituted by UNESCO after a realization that resources were rapidly being depleted, some of which will never be replaced and it guards against the pollution of the environment. The main aim of Goal Number 7 of MDGs is to avoid

ecological crisis.

Summary of benefits derived from curriculum changes

Although science curriculum changes benefitted Botswana, however, it was realized that the training of curriculum development officers was done rather late and there were no curriculum development centers. The training of curriculum development officers were required to drive and implement reforms. Curriculum reforms require well trained curriculum officers.. Prior to curriculum changes curriculum development centers were not available. The benefits of changes in the curriculum were that relevant science programmes were developed. This led to relevant examination questions. Changes were not always beneficial to Botswana. First there were no trained science teachers to implement the changes. Secondly, finance was not available to conduct workshops for teachers.

Implications for Curriculum Development

Introducing new curricula had implications teaching and learning processes. First, teachers should be trained for the new curriculum as a means to ensure that it is successfully implemented. Secondly workshops should be held for teachers to familiarize them with the new curriculum. Thirdly physical facilities must be adequately provided for schools. This requires money. Well written textbooks for the new curriculum must be provided. Therefore, there is a need for writers to have expertise in book writing. And they should also have a deep understanding of the new curriculum.

Conclusion

This paper discussed changes in the science education in Botswana. The introduction section gave a scenario of what prompted changes in the science curricula of the Western countries. The changes in the science curricula of the western countries occurred on an unprecedented scale. The changes in science curricula of developed countries had an influence on the science curricula of developing countries. The paper also discussed factors that influenced or facilitated changes in developing countries. Finally, the paper concludes by discussing the current status of science education in Botswana.

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