17. Indigenous Technology as a Basis for Science, Mathematics and Technology Education at the Junior Secondary School Level: A Sierra Leonean Case Study

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Introduction

Sierra Leone, a small developing country with a population of about 4.2 million people, lies on the West African Coast between 7 and 10 degrees north of the equator. From north to south the greatest distance is around 190 miles (320 km) and from east to west about 175 miles (290 km). Yet there is geographical diversity, with a variety of ecosystems – coastal beaches and mangrove swamps, savanna woodlands and tropical forest.

The country is divided into four regions, the western area on the Atlantic Coast, where the capital Freetown is located, and eastern, northern and southern provinces. There is considerable ethnic variety. The major ethnic groups are:

- Krios – Western area
- Themnes and Limbas – northern province
- Mendes and Konos – eastern province
- Mendes and Sherbros – southern province.

Sierra Leone is not a highly industrialised country but it can boast of a large variety of indigenous and traditional technologies that are sometimes referred to as 'cottage industries'. Each ethnic group has its own indigenous technologies although some are now common to more than one region, as shown in Table 17.1.

Table 17.1: Indigenous Technologies by Region

Western Area	Eastern Province	Northern Province	Southern Province
Foofoo/Ogirie processing	Country cloth weaving	Palmwine tapping	Garri processing
Fish processing	Extraction of vegetable oil	Gara dyeing	Fishing
Charcoal processing	Metal works	Soda-soap making	Distillation of local gin
Gara dyeing	Food preservation	Rice parboiling	Canoe and trap building
Soda-soap making	Hunting	Foofoo processing	Thatch house construction
Metal works	Fish farming	Thatch house construction	Extraction of vegetable oil

The New Education Structure

The new structure of schooling is a three-tier system that started in the 1993/94 academic session. This system consists of six years of primary education, then three years of Junior Secondary Schooling (JSS), and finally three years of Senior Secondary Schooling (SSS). In brief, it is 6-3-3-4. The 4 is for four years of tertiary education. It replaces the old system which consisted of 7 years of primary schooling and 5–7 years of secondary, followed by tertiary education.

Junior secondary school

At the end of primary schooling, pupils take the external National Primary School Certificate Examination (NPSCE), which helps placement at the JSS, at the end of which they take the Basic Education Certificate Examination (BECE). This, together with students' continuous assessment score and their profile put together by guidance counsellors, determines placement in SSS or another educational option. The JSS curriculum consists of nine core subjects – English Language, Mathematics, Integrated Science, Social Studies, Physical and Health Education, French, Agricultural Science, a Sierra Leonean Language, Religious and Moral Education. These are compulsory for all students.

Pre-vocational electives

The vocational subjects are Introductory Technology, Electronics, Local Crafts, Home Economics and Business Studies. Two non-vocational subjects are Arabic and Creative Arts. For BECE, a candidate must take all nine core subjects and three others, of which at least two must be pre-vocational subjects.

Senior secondary school

The curriculum of the SSS is wider in scope. It consists of six core subjects and a whole list of electives to be offered according to the provision in the school and the needs of the students. The compulsory core subjects are: English Language, Mathematics, a science subject, Agriculture or a vocational or technical subject, Sierra Leone Studies and a Sierra Leonean language. Nearly all the subjects now offered in the 'O' and 'A' levels are in the list of electives. For a pass in the International Senior School Certificate Examination a candidate must offer the six core subjects and two or three electives.

Science Education: A Brief History

In the past 30 years or so, science teaching in developing countries captured the attention of educationalists of many countries. Initially, attention was focused on developing elementary science education programmes. The aim was to introduce young learners to science and also prepare them for formal science teaching at the secondary level. Consideration was given to the possibility of developing junior secondary science programmes utilising indigenous cultural materials such as toys and games and natural phenomena experienced by the individual pupil.

The first major attempt at science curriculum development in Africa in which Sierra Leone participated was conceived in 1960. During the International Conference on Science in the Advancement of New States held at Rehovoth, Israel in 1960, a series of conversations was held between Rev. Solomon Caulker of Fourah Bay College, Sierra Leone and Professor Jerrold R. Zacharias of the Massachusetts Institute of Technology (MIT). These conversations led to a mutual agreement to explore the potential application of modern curriculum development techniques to the educational needs of Africa.

The Caulker-Zacharias conversations led to an initial conference held in MIT's Endicott House in July 1961 out of which evolved the African Primary Science Programme (APSP). The APSP prepared appropriate materials for teaching primary science in the Anglophone African countries that participated in the programme. Local materials such as bamboo sticks and discarded items such as empty tins, jars, bottles and bottle tops were used in developing improvised equipment for primary pupils to experiment with. Teachers' guides were also developed for approximately 50 units, all of them emphasising the use of local materials and natural processes in the environment.

The ripple that APSP generated was felt throughout the English-speaking African countries. By the time APSP metamorphosed into the Science Education Programme for Africa (SEPA), a critical mass of science educators in Africa had been developed. Extensive revision of science education policies with clearly defined goals started emerging in many African countries.

In 1976, the Government of Sierra Leone committed itself to the diversification of the secondary school curriculum. This led to the development of the Core Course Integrated Science (CCIS) for the junior secondary school level. Bockarie (1982) found out that because there was no government policy making the use of CCIS mandatory in all secondary schools, the majority did not use it. Hence it lasted only five years.

In 1983, when the 6-3-3-4 system of education was being planned for all English-speaking West African countries, the Ministry of Education delegated responsibility for developing a national curriculum to the Institute of Education (the arm of the university responsible for curriculum development activities). After a series of meetings, the subject areas agreed on included Language Arts, Science, Social Studies, Mathematics, Home Economics, Agriculture, French and Technical Subjects. The science curriculum proposed was not high technology driven because Sierra Leone was, and still is, not sufficiently economically strong to develop and maintain such a curriculum. Besides, Sierra Leonean children need to be taught science relevant to their situation.

The State of Play

For the past three decades or so, Sierra Leone has been in a state of severe economic depression. This has led to very low teacher morale and the steady deterioration of the standard of science teaching in the country. Teachers do not commit themselves fully to their work in a system that seems to care very little about education. Added to this, many of those who are still left in the system are inexperienced, unqualified and have to deal with overcrowded classes of indisciplined pupils. It is not surprising that their classroom style is one of survival characterised by dependence on the textbook or dictated notes. Teachers have clung tightly to this didactic approach of teaching because it seems the easiest (though not the best) method, given the present circumstances.

Spencer (1993) outlined the problems affecting science education in a declining economy at secondary school level which she observed during four years of teaching practice supervision and informal discussions with student teachers and regular science teachers in different parts of the country. The problems were:

- Lack of adequate textbooks;
- Reading difficulty of the available textbooks;
- Lack of funds to purchase equipment, chemicals and for improvisation of some simple apparatus;
- Overcrowded classrooms, laboratories and timetables;
- Shortage of qualified and trained teachers;
- Pressure of external certificate examinations;
- Lack of co-operation between government and school administrators;
- Lack of motivation among teachers with very low morale and status;
- The use of archaic teaching methods and materials foreign to pupils background;
- Poor attitude of pupils to academic work;
- Prevalence of superstitious beliefs and the general lack of a reinforcing home environment.

If the education system is to fulfill its aim of producing well-rounded Sierra Leoneans capable of successfully interacting and integrating with their physical and social environment, then it is obvious that something needs to be done. The use of indigenous technology in teaching science is one way of solving some of the problems identified. The Sierra Leonean environment is rich in local resources which could be used to teach science, maths and technology in a meaningful way. This chapter is an attempt to draw attention to this and show how our indigenous materials and technologies can be used for this purpose effectively.

Indigenous technology

What is it?

Indigenous technology has been defined as the traditional methods and skills concerned with the production processes which transform locally available materials into products. These products are either for sale or for domestic consumption or use (Amara, 1987).

Makhubu (1988) pointed out that in contemporary literature, indigenous technology is referred to as the techniques and practical skills and crafts which are rooted in local traditions and customs passed on from one generation to another. In this discussion, the expression 'indigenous technology' is used to denote the traditional methods and skills used in the production processes in cottage industries in Sierra Leone.

A survey of rural technology by Cole and Hamilton (1978) revealed that in Sierra Leone there is a vast array of rural technologies. Among other things, this survey identified the range of available indigenous technologies that could be employed in attempting to develop new science curricula for primary and secondary schools and also showed that children (school-going or not) are involved in carrying them out. These indigenous technologies have been organised into the following classification:

Food Technology – fish, oil, salt, foofoo and so on;

Clothing Technology – country cloth wearing, gara, and ronko dyeing;

Household Technology – soap, charcoal processing and so on;

Metal Technology – such as coal pots and farm implements;

Trap Technology – wild animals, fishing;

Bamboo Cane Technology – furniture;

Construction Technology – thatch house and bamboo fronds woven into sheets.

This classification has been based upon the most important materials used in the technology, or the use that is made of the technology. For the purpose of curriculum development, these technologies are classified according to the scientific processes they exemplify.

Technologies exhibiting chemical processes are: extraction of vegetable oils and salt; manufacture of soap, lubi, snuff, dyes and dyeing; and charcoal processing and metal working.

Technologies exhibiting physical processes are exhibited in construction processes – house-building, canoe and trap building – and in hunting, fishing, weaving and drawing water.

Technologies exhibiting biological processes are: foofoo (pounded fermented cassava), garri (parched, grated cassava) and ogiri (fermented sesame seeds) processing; palm wine tapping and distillation of local spirits; fish farming and fish preservation; and rice parboiling.

Technologies exhibiting mathematical concepts are: measurements of weights and volumes in chemical processes; lengths in physical processes; and time and statistical data in biological processes.

Why Indigenous Technology?

It is certain that the world will eventually be dominated by modern technology and therefore it would appear to be a retrograde step to be advocating the use of indigenous technology in the new millennium for teaching mathematics, science and technology. Nevertheless, indigenous technology is still widely used in Sierra Leone and therefore constitutes an important part of a large majority of the students' (both rural and urban) environment and lifestyle. It is important to introduce at an early age the idea that what is indigenous is not static but can be modified in order to improve its efficiency and productivity. If our schools are to impart basic, relevant and usable knowledge, this area cannot be ignored because with indigenous technology, the starting points for learning are real, everyday activities and problems that have science and technology components, instead of starting with abstract concepts and processes.

When studied by students, indigenous technology will exemplify scientific, mathematical and technological principles and processes. Although questions have been raised regarding the fact that some of the chemical and biochemical processes involved with local materials and processes will be too complex and not understood by 12–14-year-old students, the usefulness of such materials for instructional purposes have been investigated by Cole (1979) and Spencer (1993). In the modules on energy based on the 'coalpot' (a locally constructed charcoal metal stove) and 'Gara', Spencer showed how indigenous technology deals with issues that are relevant to society in addition to science and technology concepts. For example, in the module on energy, pupils leaned about:

- Science concepts, such as forms and sources of energy, heat transfer and loss, and energy transformation;
- Mathematical concepts, such as measurements of time, volume and weight, percentages and the need for accurate repetition;
- Technology processes, such as determining the efficiency of various models of coalpots, and the design and construction of an energy-saving model;
- Environmental concepts, such as the effects of tree-cutting and burning on the environment and wildlife, and the efficient use of energy and fuels.

She further revealed the potential for further development of these indigenous materials as a base for industrial exploitation. The elementary treatment of these local technologies and materials will motivate both the primary and secondary pupil in learning the sciences, mathematics and introductory technology because indigenous technology can provide pupils with opportunities to:

- Identify problems with local interest and impact;
- Use local resources (human and material) to provide information that can be used to solve problems;
- Extend their learning beyond lesson time, classroom and the school to their communities;
- Develop a certain amount of autonomy in their learning, particularly as they identify individual issues.

This approach is therefore a conscious attempt to allow pupils to become actively involved in the process of learning, instead of passively receiving the teacher's flow of information.

Supporting the inclusion of indigenous technology in both the formal and informal education programmes, Chaytor (1991), a well-known Sierra Leonean scientist and science educator, said:

At the base of every indigenous technology, there is a science, the proper understanding of which permits the mastery, adaptation and improvement of the technology. Education should promote the understanding of the relevant science so as to nurture ingenuity, innovation and improvisation.

There is no doubt that indigenous technology, by providing settings and opportunities for considering basic science, technology (reinforcing mathematical) concepts and processes at the same time, has the potential to help pupils develop the necessary scientific and intellectual skills that they have been deprived of in the traditional teacher-dominated learning situations that usually lead to rote learning.

Finally, the value of using indigenous technology can also be seen in the light of current trends in science education. Thus it links science with technology; it places science in a social context and provides opportunities to introduce issue-based studies. And by associating pupils' conceptual development in science with their commonplace understanding, it enables the values of a constructivist approach to teaching to be exploited.

Indigenous Technology and Science and Maths Teaching

How does indigenous technology fit into all this? The familiarity and the local nature of the materials and processes being explored will enable children to understand elementary scientific, mathematical and technological principles which would be difficult to comprehend if they were foreign to their experience or merely elaborated for direct delivery in the traditional teaching manner.

Maruping (1976) taught reactions of acids and bases to groups of secondary school pupils in Bo and Taiama in Sierra Leone using potassium hydroxide and Sierra Leone 'lubi' (a vegetable-derived material) as bases. She concluded that although lubi was a local material with apparently more impurities than the imported laboratory reagent, the effectiveness of the reactions was the same for both substances. Lubi had all the properties of a base and the quality of conceptualisation by the pupils was high compared with that achieved when imported materials were used.

The use of indigenous technology and materials to study science, mathematics and technology offers pupils an opportunity to carry out the scientific processes of observation, data collection and recording, computing and making generalisations. In terms of acquisition of scientific knowledge, pupils do not miss out on anything they should know at a particular level. In Forms 1, 2 and 3, some of the concepts specified in their science and mathematics syllabuses can be taught using the indigenous technologies set out in Table 17.2.

Table 17.2: Indigenous Technology and the Various Concepts Involved

Indigenous Technology
'Omole' (local gin) production
Salt and oil extractions
Extracting and drying materials
Food production ('foofoo', 'ogirie', 'ogi', fish processing)
Gara dyeing
Coal pot – construction and use
Charcoal processing

Scientific Concepts/Processes
Distillation solutes, solvents solubility and solutions
Density
Evaporation, filtration
Fermentation, osmosis, microbiological actions – bacterial, enzymatic, fungal
Colours, oxidation, solar energy, rainbow
Properties of metals, energy, heat transfer/loss
Fuel and burning in a limited supply of air – co – co^2

Mathematical Concepts/Processes Measurement – weight Volume, time Length, Temperature, quantities, ratios Proportions Geometrical shapes Percentages, statistical analysis
Technology Concepts/Processes Technology process Efficiency of system Structures, strength of materials Conservation Recycling – compost production and use (organic farming)
Environmental Educational Concepts Pollution Deforestation – erosion

In Form 3 (JSS 3), pupils can be taught fermentation, microbiological action and oxidation. Pupils can carry out small-scale investigations on the suitability of materials used, and ways of improving conditions and processes. Measurements and tests can be done in all instances and data recorded for analyses and where appropriate reagent tests can be done in impure and purified materials to determine reactions with reagents and changes that take place with purification.

For each indigenous technology listed in Table 17.2, concepts can be taught from science, mathematics, technology and environmental education. Take 'Omole' (local gin) production, for example. A teacher can teach about distillation, vaporisation and condensation, measurement of volume and temperature, efficiency of the production system, cost-effectiveness, fuel types and their use, pollution and the effects of deforestation.

On the whole, the table shows that indigenous technology is not about single concepts, as science and mathematics are. It is about multiple concepts, including a combination of science concepts and concepts from other disciplines.

Indigenous Technology and Technology Teaching

In this discussion, technology is seen as any method, thought process or idea (however small) that leads to a better state of affairs. The focus is not so much on the invention of new machinery and equipment, but on the skills, abilities, knowledge, system and processes necessary to make things happen. The technology used in indigenous technology has been evolved by people in their particular locality to solve their own problems.

The introduction of technology as a subject into the general education system in Sierra Leone has been hampered by such things as lack of qualified staff, facilities, the necessary policy and time-tabling difficulties in the system itself. Nevertheless, indigenous technology and the rich collection of cultural objects with scientific bases could serve as valuable starting points for the introduction of technological skills. The technology used in the indigenous practice being studied should be identified and understood before pupils are given an opportunity (in the form of projects or problems) to see what improvements can be made.

From the indigenous technologies that involve construction of devices, pupils will learn to recognise common patterns of structure and interactions and attempt to explain such patterns. Hypotheses will be formulated and tested and experiments will be performed through actual pupil activities using indigenous materials, thus linking what is familiar in the child's environment with the new scientific or technological knowledge and understanding that is to be acquired. These objects and processes can also, by themselves, serve as problems for investigation.

The design and construction of artefacts should be studied as and when the need arises. The following questions could be used as guides for pupils:

Is the construction of an artefact necessary? What should be constructed? How is it to be made? How does it or will it work? This aspect of the work has two dimensions: an intellectual aspect that involves the design of the artefact, which calls for creativity; and a practical aspect that calls for imagination, initiative, manual dexterity and form and detail recognition, as well as planning and organisation. Technology, whatever its form, has basically these two dimensions.

Introducing Indigenous Technology into the Syllabus

Two approaches can be used. The first is the inclusion of indigenous technology as a subject, as is currently being done at the Young Women's

Christian Association (YWCA) Vocational Institute in Freetown. The second is to integrate it into the science syllabus.

In Sierra Leone, because the science syllabus is organised on the following themes – science and society, matter, energy, universe, continuity and change – the latter approach is likely to be favoured. After examination of the five themes, the author concluded that only continuity and change was not suitable for integrating indigenous technology. Integrating indigenous technology into the current science syllabus will allow co-ordination between themes, make cross-curricular and interdisciplinary approaches more meaningful, and will also provide opportunities for understanding the role that science and technology can play in helping to identify and resolve local problems.

Teaching methodologies

The recommended teaching strategies are child-oriented and activity-based and can be achieved through projects, follow-up activities, field trips and the involvement of non-teaching resource persons from the community. Guided discovery method is advocated with suggestions for (learning) activities to be done in the classroom, laboratory, outdoor and in the community. Teachers are encouraged to adapt the materials to the needs and abilities of their pupils. It is also worth noting that for this level (Forms 1–3), no elaborate or sophisticated laboratory facilities are needed. Pupils will look at ways of applying scientific, mathematical and technological principles to solving problems from their homes, local community and hopefully from the nation as well.

The roles of the teacher in indigenous technology

The majority of Sierra Leonean children are familiar with some aspects of indigenous technology. Rural children and a majority of their urban counterparts are familiar with both the processes and the products. However, a majority of urban children are more familiar with the products than the processes. This means that the children already have ideas about the subject and this may have a major influence on learning. Teachers should, therefore, devise a methodology to ascertain the particular ideas children hold. In this way the teacher assumes the role of a 'diagnostician'. Freyberg and Osborne (1985) explain that, in order to diagnose children's existing knowledge, teachers must provide plenty of opportunities for pupils to express their ideas, whether in small groups or whole class settings. But this alone is not enough. Teachers need to ensure a classroom climate where children's ideas are valued and listened to. The teacher can also diagnose pupils' framework of ideas by analysing not only their incorrect answers to questions in class and examinations but also their reports on laboratory work based on indigenous technology or devices.

In addition, the teacher must take on the role of a guide to enable pupils to link their experiences with indigenous technology to accepted scientific ideas. The teacher as a guide should provide pupils with many examples and applications of science to indigenous technological processes and materials. The teacher should also encourage further elaboration of the idea by having pupils consider it from a number of points of view, both as individuals and in small groups.

Assessment

Assessment is an issue that is bound to raise questions in relation to the inclusion of indigenous technology in the curriculum. This is because teachers and pupils alike recognise that assessment procedures reflect the goals of teachers and school, and that many pupils put their best efforts into activities that will be rewarded. In addition, from the kinds of activities involved in different indigenous technologies, some people may find it easy to assess in the psychomotor domain only and may have difficulty determining how overall assessment can be done.

However, through the work of Cole (1979) and Spencer (1993) who used achievement tests, laboratory performance tests and project reports, it can be seen that in assessing pupils' cognitive achievement, it will be necessary to determine their:

- Recognition of different classes of materials, their interactions with other substances and the products of such interactions;
- Applications of scientific principles in certain situations involving indigenous technological processes;
- Ability to solve problems related to indigenous technology processes.

In the domain of affective behaviour it will be necessary to ascertain:

- The level of pupils' interest in science as shown by the readiness to discuss scientific matters related to local technology, environmental conservation and topics of local or international relevance;
- Pupils' enjoyment and willingness to carry out activities related to the course;
- Pupils' recognition of problems of scientific interest out of school, at home or in interaction with peers;

- Pupils' increasing understanding and pride in indigenous technology and cultural practices.

Conclusion

Some teachers and educationalists see indigenous technology as progressive, while others see it as an irrelevant and retrogressive approach to learning science. However, there is no doubt that work and studies done by researchers such as Cole (1979), Makhubu (1988) and Spencer (1993) show that pupils enjoy it and have been able to understand certain scientific, mathematical and technological concepts better. Indigenous technology has been found not only to enrich teaching by providing variety in what would have been 'chalk and talk' lessons, but also to enhance teacher-pupil relationships.

Every country has its own indigenous technology that can be researched and used in the classroom as a basis for the teaching of science, mathematics and technology, using the Sierra Leonean mode. This will not only be a step in demystifying science, mathematics and technology, but will add to the preservation of the country's cultural heritage. In this way, society is brought into the classroom in ways that will subsequently make learning more relevant to the everyday experience of the child.

To achieve this, teachers should be provided not only with the necessary teaching materials but also be given in-service and pre-service training, because a change of approach is necessary if a good job is to be done.