15. The Contribution of Applied Science to the Popularisation of Science and Technology: A Ghanaian Case

Professor Jophus Anamuah-Mensah
University College of Education of Winneba, Winneba, Ghana

Background

This chapter reports on science and technology projects aimed at broadening the knowledge base of junior and senior secondary school students and their teachers by linking school science and technology to industry. The projects are based on the principle that the popularisation of science and technology can best be accomplished through teaching the application of science, thereby generating meaning and relevance.

Some consider that applied science consists of 'those processes through which man has successfully interacted with their environment, and used natural resources to construct their world'. For Mukhurane and Kahn (1999), applied science is that which 'enables people to add value to their resources, is itself problem solving in its execution, and blurs distinctions between science, technology and on occasion sociology.'

The chapter looks at previous attempts to introduce applied science into science and technology education. It is argued that though the formal educational system provides opportunities for students in schools to learn science and technology, this has not been successful in making all of them science and technology literate. This is partly due to the purely academic and elitist orientation of the science and technology curriculum, as well as to its neglect of the socio-cultural environment of the learners.

Introduction

The education of Africans during the pre-colonial era has been described as relevant, practical and work-oriented and was aimed at making every citizen useful in the society. According to Brock-Utne (1999), education during this period was linked to practical reality. There was a clear link between education and productive activities, between education and social life, and between education and the culture of the people. Education at the time was therefore relevant, embracing the totality of the people's culture. The extraction and smelting of iron, blacksmithing, bead making and kente weaving were some of the productive activities carried out.

This indigenous, practical-oriented, applied science was lost during the colonial era. The introduction of Western education alienated students from the indigenous activities of the community as a result of the marginalisation of ancestral knowledge and know-how, which was seen as a counter system.

The Western science bequeathed to African countries was in general an academic and elitist training given to only a few to provide the services needed by the colonial masters. The orientation was therefore more towards satisfying the colonising countries' thirst for power than to addressing development issues raised either directly or indirectly by Africans themselves.

At the time of independence of most sub-Saharan African countries, which incidentally coincided with the curriculum reform movements of the UK and USA, science education was still elitist and academic, even though the curriculum promoted the empiricist perspective.

In Ghana, with the expansion of the economy immediately after independence through the establishment of industries in rural and urban areas, there was a realisation that the white collar jobs which used to be readily available to school leavers were no longer available. The school system became increasingly dysfunctional as it turned out school leavers who had no marketable skills. According to Dzobo (1987), 'these school leavers could see no bright future for themselves and they constitute a veritable economic and social problem for our society to solve'. People were disillusioned about the education they were receiving.

It is interesting that the dissatisfaction with the academic lopsidedness of formal education was not new. As far back as 1847, Africans and colonial administrators in Ghana recognised this, but it was not until the 1920s that the first technical school for agriculture was established as a result of the Phelps-Stokes report.

The major criticisms were that science education was not relevant to the needs of the economy and that it considered the culture of the people to be primitive with Western science being the superior culture that should replace the indigenous culture. It therefore projected the Western world view as the only legitimate view (Jegede, 1997).

In 1967 there was a shift in government policy which favoured the introduction of vocational technical education in the form of continuation schools. This was a welcome innovation at the time since it offered an alternative path for pupils who were not able to gain admission to the grammar-type secondary schools through the common entrance examination. This examination was designed to select pupils in Forms 1 and 2 of middle schools and Class 6 of preparatory schools for secondary schools.

The Continuation Day Schools in Ghana

Prior to the formation of continuation schools, the following issues characterised the education system. Pre-university school education followed a single path with everyone expected to move through six years primary, four years middle, five years secondary and two years sixth form education. No provision was made to cater for the special abilities of students.

- The common entrance examination system cut off 80 per cent of middle school leavers from continuing their education (Bishop, 1986).
- Middle school leavers were not equipped for the world of work or to create jobs for themselves.
- The public had a negative attitude to manual work, preferring white-collar jobs to practical vocations
- There was a constant stream of school leavers from the rural areas to urban towns resulting in underdevelopment of rural communities.

The two-year continuation day schools were introduced to address these conditions by bringing practical work into what was described at the time as a traditional, examination-oriented academic curriculum. The work of the school was designed to relate to what school leavers would face after school in their communities. The existing middle schools were converted into continuation schools that devoted a third of their time to practical activities that helped pupils to develop productive skills and techniques as well as to produce objects with an economic value. Village craftsmen were used as paid specialist teachers to share their expertise with the pupils. Activities covered in the curriculum included animal rearing, crop and vegetable production, kente weaving, production of sandals, baking and cooking, and needlework (Bishop, 1986).

The introduction of the continuation schools initially met with some resistance because 'farming parents did not want an education that would bind their children to a life of toil on the soil: they preferred time honoured academic education' (Bishop, 1986). However, with the embracing of the government's 'Operation Feed Yourself' philosophy, community support increased to the extent that by 1973–74 the number of continuation schools increased about 2600 per cent from the initial 18 trial schools to 467. This was, therefore, a very successful innovation that introduced applied science in the form of technical and vocational subjects into the curriculum although it did not cater for all students.

The continuation schools were phased out in 1980–81 when they were fully incorporated into the experimental junior secondary schools concept of making education both terminal and continuing. This was to ensure that all pupils were predisposed to vocational and technical skills.

Alternative Approaches

Other innovative strategies to introduce applied science into the academic curricula of schools are the village polytechnics in Kenya and the brigade movement in Botswana. The village polytechnics were established to overcome the growing unemployment of primary school leavers and the drift from rural to urban centres in search of a better quality of life. The village polytechnics were community vocational schools that were built, staffed and managed by the community to provide vocational training for primary school leavers for two years. Both academic education and practical training were offered, based on local needs and including subjects such as agriculture and commerce. The ultimate aim was to make the graduates self-employed. Parents and the public, however, saw the village polytechnics as offering second or third class education.

The brigade movement in Botswana was set up in 1963 to address the perennial unemployment problems of primary school leavers. It provided a three-year vocational, technical training that combined work and learning. Depending on the nature of the craft to be learned, a number of brigades were set up. Examples are the builders' brigade that involved putting up structures and carpenters' brigade that involved the making of desks, beds and so on. The training programme consisted of a period of production work and 'on-the-job' training, classroom instruction in vocational subjects and classroom instruction in academic subjects. Even though the brigades provided an alternative route to secondary level education, they were considered as second-rate education for those who failed to get into the regular secondary schools.

Although the continuation schools system was generally a success, a number of criticisms were made of it.

- It encountered negative reactions from the public. Many parents of children in the public school system, especially educated ones, forced their children to sit for the common entrance examination to escape going to continuation schools. This was attributed to the undue emphasis the education system placed on mental work, which unintentionally fostered the development of unhealthy attitudes towards manual work and non-academic subjects.
- It was seen as a tool for separating academically oriented pupils who entered the grammar type of secondary schools from the less academically oriented who received vocational skills and were perceived as dropouts and 'uneducables' (Dzobo, 1994).
- The continuation schools did not provide adequate training to enable the pupils to become self-employed after graduation.
- There were no avenues for further training in the vocational areas chosen by the pupils except in privately run apprenticeship programmes.
- The schools did not give an opportunity for all pupils to be exposed to practical skills.
- It is clear, however, that these efforts to introduce vocational and technical subjects into existing theoretically-based educational systems provided opportunities for a reasonable number of people to be exposed to some form of technology education.

Genesis of the STAG Project

The emergence of the Science and Technology Action in Ghana (STAG) project can only be understood in the context of the 1987 educational reforms which brought about major structural changes and mental adjustments. The reforms became necessary as a result of concerns raised about the educational system at the time. The concerns expressed about science and technology education were as follows:

- Science education at the secondary level was elitist, academic and theoretical;
- Science and technology education portrayed only the modern Western view of science and technology and was therefore not related to the environment and culture of the learners. It was therefore seen as alien and irrelevant;
- Science was perceived as a culture-free activity, which can be taught to all regardless of the receiving culture (Turner and Turner, 1987);

- Many pupils who failed to gain admission to secondary schools did not have the opportunity to develop their minds and were therefore disadvantaged for life;
- Foreign textbooks used in the schools transmitted Western 'socio-political values, not just openly but also by omission with a biased presentation of facts' or indirectly when the values are hidden in an exercise or task (Goldstein, 1978);
- There was a lack of political will to implement the recommendations of the reports of the Educational Advisory Committee (1972), also referred to as the Dzobo Committee, set up to review the educational system;
- Increasing numbers of unemployed school leavers lacked practical skills and were ill-equipped to fit into the economy;
- The teaching of science lacked the applications of science in and around the environment of the learner and especially in industry.

As mentioned above, these and other factors culminated in the educational reform movement in 1987. The reform:

- Introduced a 6-3-3-4 system of education, that is, 6 years primary, 3 years junior secondary school (JSS), 3 years senior secondary schools (SSS) and 4 years tertiary education;
- Echoed the continuation school concept of providing pre-vocational and pre-technical education for JSS students, thereby introducing practical work into the traditionally academic curriculum of schools;
- Introduced a multiple trajectory system at the SSS level through diversification of the curriculum which now enables students to pursue either a purely academic curriculum in science or applied science programmes such as agriculture and technology in the same senior secondary school;
- Included topics on science, industry and the environment in the science curriculum at the senior secondary and recently at the junior secondary levels;
- Advocated a shift in orientation from 'euro-academic excellence' with its emphasis on European standards to socio-cultural relevance with its emphasis on the culture of the people and work-oriented skills;

The STAG project originated in 1987 at the University of Cape Coast (now being hosted at UCEW) in response to the need to bridge the growing gap between school and community science and technology. It also sought to provide industry related materials that were needed to teach the science-industry-environment topics in the new syllabuses. It has currently produced materials for 15–18-year-old senior secondary school students.

What Science and Technology?

Our earlier discussion indicates that pre-colonial education of Africans was designed to be responsive to communities' practical needs and covered the totality of their social and economic life. The productive activities of African societies featured prominently in their education that was therefore application-oriented. The advent of Western education during the colonial era changed the focus by giving emphasis to academic orientation and the marginalisation of the applied nature of the indigenous science and technology education. This practice has continued to the post-independent era with vocational and technical education still not recognised as a first-rate education in our schools.

For a long time there has been concern that science taught in schools does not enable students to use their knowledge to solve problems in their homes and communities. It was theoretically oriented and driven by external examinations. It is said that, for example, many graduates of the school system found it difficult to change blown fuses in electrical plugs. However, critical observations indicate that in the community, home, farm and workplace, science manifests itself as science-in-use or science-in-reality, that is, as applied science. This is in contrast to the school, which generally promotes science as theoretical and mythic (Smolicz and Nunan, 1975). This creates a gap between the applied science in the community and the pure science view of school. The STAG project promotes an applied science view and therefore brings aspects of the community, especially industry, to the science classroom in some form. For example, the concept of flotation is presented as it is applied in the gold industry.

Whose Science and Technology?

The adoption or adaptation of Western science by post-independent African countries was accompanied by the culture, that is the values, norms and customs, of the country of origin. This culture shaped the thought, feelings and actions, and the world view of students. Culture has been described as the webs of significance people spin for themselves and in which they are suspended (Geertz, 1973). The webs include the values, norms, indigenous technologies and their links to school science and technology and 'out-of school living' (Solomon, 1996).

If culture is an important variable in science education (Ogunniyi *et al.*, 1995; Jegede and Okebukola, 1988; Ogawa, 1986; Ogunniyi, 1987, 1988), then community culture and knowledge should determine the science education content and delivery in our schools (Jegede and Solomon, 1999).

The STAG project promotes science and technology which are derived from Ghanaian culture. The industries in the country served as the base for this. For the first time, industries were asked to help determine the curricular content. Industries in Ghana were recognised as the locus of applied knowledge while science teachers were deemed to be the custodians of pedagogical knowledge and skills. That is, the teachers' role was to consider how to make the applied knowledge of industry meaningful to themselves and their students.

The account of the industries presented in STAG materials is the result of a distillation process that saw the removal of highly technical terms and complex illustrations and yet produced authentic accounts. The essence was to make the applied science located in industries available to students.

Science and Technology for What?

According to Skilbeck (1984), any educational discipline such as science education has three fundamentally different purposes – cultural transmission of knowledge, vocational needs and societal reconstruction.

The first purpose requires that the accumulated knowledge of science and technology is passed on to the next generation of research scientists who will help to push back the frontiers of knowledge. This is what Makhurane and Kahn (1998) have alluded to as high science.

The second purpose, preparation to meet vocational needs, although important for the development of developing countries, is hard to find in school science education. This requires that students are given core transferable skills that will enable them to secure jobs as middle-level manpower. Such skills necessarily include familiarity with science as practised in industry, a positive attitude to science and the desire to learn about industry. The 1992 industrial policy of Ghana states that industrial development requires human resources with scientific skills as well as 'appropriate general skills and the motivation to acquire and develop specific skills on-the-job' (Republic of Ghana, 1992). This vocational purpose of science education is related to Makhurane and Khan's (1998) low science. The lack of this vocational orientation of science education has contributed in no small way to the underdevelopment of most African nations.

The third purpose, reconstruction of society, involves inculcating what is variously called 'scientific culture', 'scientific and technological literacy' and 'public understanding of science' in the population. In this era of great scientific and technological achievements that impinge on the day-to-day lives of every citizen, it is the democratic right of every citizen to be fully involved in the scientific and technological culture. Every individual should be provided with an understanding and appreciation of science and technology concepts as they relate to their daily lives. They should also develop a positive attitude to science and technology and should find them enjoyable. Issues such as deforestation, irradiated food, trade in human organs, ozone layer depletion and *in vitro* fertilisation require informed decisions based on science and technology. We need to help youth to engage in discussions of such issues.

Public support for science and technology education and research will depend on the culture of science and technology created in society. The STAG project has attempted to provide a vocational orientation as well as creating the platform for a scientific and technological culture. This has been achieved by introducing both teachers and their students to applications of science in indigenous and modern industries operating in the country. Materials for 18 industries, including steel, gold, petroleum refining, cement, aluminium, wood, textiles, beer, cocoa and soap, have been developed to expose students to applied science. These constitute the economic backbone of the community and also provide employment opportunities for a large percentage of the country's school leavers (Towse and Anamuah-Mensah, 1991).

Many senior secondary schools are using the STAG materials to help them interpret the 'Science, Industry and Society' section of the science syllabus. The students' workbook provides practical investigative activities (projects), as well as games, case studies and role-plays that enable students to engage in discussions and debates about issues related to industry, such as pollution and improvement of an industrial product. Activities are provided to enable students to construct an environmental impact profile (ecoprofile) for each industry.

The project has produced a resource book for science teachers, a students' workbook and video clips on some industries. The last two will soon be available on the market.

The resource book, *Science in Action: A Resource book for Science Teachers*, consists of 20 chapters, 18 of which discuss specific industries. The other two chapters are on broader issues that concern all industries. Each industry is presented according to the following sub-headings: introduction, highlights on industry, production or manufacture of a specific product, raw materials, production processes, quality control, uses, safety and future development.

The students' workbook is organised according to the chapters in the teachers' resource book. For each chapter there are games, case studies, role-plays, projects and an ecoprofile. They have been developed to engage students in investigative activities, provide fun through the games and engage in discussion of social issues relating to the industries through role-plays and case studies.

Role Play: Potassium Bromate in Bread Making

Introduction

Potassium bromate is commonly added to improve the quality of flour. It acts as both an oxidizing and bleaching agent and is reduced to potassium bromide (KBr). This is toxic and harmful when excess potassium bromide is produced. Ascorbic acid that is not harmful may be used as a substitute for potassium bromate.

The Role Play

Recently bakers in the bread industry have been disturbed over poor sales because of the publicity about potassium bromate (KBr03) in the flour. During their Fifth Annual Congress, the President of the Bakers' Association sent a memo to the following inviting them for a discussion on "Potassium Bromate in the Bread Industry":

The President of the Ghana Chemical Society whose concerns include the harmful effects of bromate and the advantages of ascorbic acid;

The Director of the Ghana Standards Board concerned about certification of ascorbic acid in flour and sanctions that might be meted out to defaulters;

The Chairman of the Flour Millers' Association who is sensitive to the public's reluctance to buy bread and other bakery products;

The Chairman of the Consumers Association which fears cancer and is aware of a possible need to destroy any foodstuff containing bromate.

Instructions

Write appropriate memos as: a) the President of the Ghana Chemical Society, b) the Director of the Ghana Standards Board, c) The Chairman of the Flour Millers' Association, and d) the Chairman of the Consumers Association.

Lessons Learned

A major problem the project encountered was to ensure that the materials reflected a truly Ghanaian setting and did not just present these processes in a culturally neutral way. This became a thorny issue for some time. It was, however, addressed by incorporating indigenous technologies, socio-economic issues and other situation-specific information.

Contextualising the presentation posed difficulties in publishing the materials. It is noteworthy that two multinational publishers rejected the final manuscript of the resource book as being 'too Ghanaian'. A Ghanaian publisher, after reading the manuscript, decided to publish the book.

The interaction between industrialists and teachers provided an opportunity for shared meanings. There was openness in these interactions and bonds of friendship were established, making it easier for the project team to have access to industrialists' knowledge and their factories.

The involvement of industry as curriculum partners has created a larger community of knowledge producers and transformers. In the past, teachers were regarded as the sole producers of classroom knowledge, probably because they are deemed as possessing pragmatically-validated knowledge about teaching, learning and school organisation (Richardson, 1994). However, with the emergence of what Gibbons (1998) refers to as the 'global distributed knowledge production-system', that considers production of knowledge by other groups such as industrialists, the inclusion of industry in the project broadened the sources of classroom knowledge.

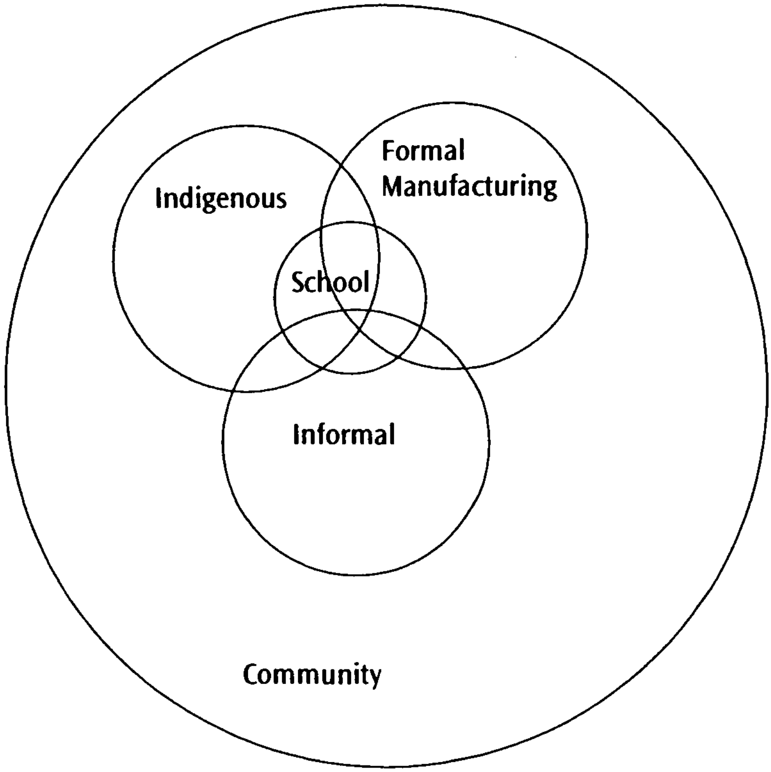
The involvement of industry and the general enthusiasm generated has encouraged several industries to make financial contributions for reprints of the books.

Industrialists seemed more willing to respond to reviews drafts of their industries than to produce drafts themselves.

The discussions, reviews and re-writing served to reduce the technical information, yet provided an authentic portrayal of the industries.

The STAG materials constitute the first set of locally produced resource material available to science teachers. Hitherto, the textbook has been the main source of information for science teaching and learning. It is believed that more than 95 per cent of science teachers use the science textbook more than 95 per cent of the time as the source of notes, practical activities and assignments.

Fig 15.1. Major areas of study at SACOST



What Next?

With STAG materials now being used in science classrooms, the next activity is to evaluate their use in schools. Observation instruments and other industry-based test instruments will be developed for this purpose. How the science teacher uses the materials will be of great interest to the project. The project intends to develop industry-oriented examination items and other authentic assessment tools. Already some items in the external examinations conducted by the West African Examination Council for junior secondary schools have an industrial bias; this will be encouraged through discussion with the Ministry of Education. The project intends to maximise the good relations it has developed with industries to establish a partnership between industry and schools and universities. This will involve, among other activities, the use of industrialists as guest lecturers and part-time teachers. The partnership should allow for short industrial attachments for students during the long vacation and assist students to develop industry-based projects. The formation of a Centre for School and Community Science and Technology Studies (SACOST), a node of excellence for bridging school and community science and technology at the University College of Education of Winneba, Ghana, will help to co-ordinate all the above activities. The centre will spearhead studies leading to the development of teaching and learning materials on activities in the informal and indigenous sectors of the economy as well as adding value to those sectors, and will be a reference centre for studies in these areas. Figure 15.1 gives the major areas of study at the centre. It is envisaged that these activities will lead to increased access to science and technology for all pupils in schools and for those in adult education irrespective of gender.