The Development and Production of Low-Cost Improvised Mobile-Micro Science Apparatus and Kits

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Abstract

Science education imparts a method of inquiry and a systematic way of processing knowledge about the physical world. For this reason, science education provides part of the foundation for any knowledge-based inquiry. This paper presents results from the first stage of a three-stage project, designed to improve the learning of science by students through laboratory practical work activities. In Nigeria, one of the limiting factors for teaching Science in schools is the non-availability of even the most basic equipment for use in demonstration and laboratory exercises. Shortages of chemicals and equipment mean that teachers replace student experiments by teacher demonstrations or merely describe experiments and their outcome. Such practices are at odds with the expressed aims of science education. The first phase of this project involves the development and production of improvised low-cost apparatus and science kits that students could easily purchase and carry out their laboratory experiments on their own at home. The second phase of the project will involve the writing of students' and teachers' manuals that can be used with the improvised resources made. The third phase of the project will seek to address the very difficult problems of maintenance. Such a problem has been recognized by UNESCO where it emphasizes that necessary steps should be taken for maintenance and care of materials after use. The major contribution to knowledge is that as a nation we need to be self-reliant especially in the development and manufacture of science education equipment and kits. Hence, this project should therefore encourage the establishment and development of small-scale enterprises in the area of equipment manufacturing. If the equipment is also low-cost, then it is more likely that it will be used in the classroom.

Keywords: Science education, laboratory practical work, laboratory equipment, demonstrations, improvised apparatus, science kits and maintenance.

Introduction

The importance of science and technology education in national development has been well documented in the literature. Furthermore, the National Policy on Education places adequate emphasis and significance on science teaching and learning in the curricula of all levels of education. Even though government policies on science education have been consistent and clear over the years, there have been problems with the implementation of such policies. Ivowi (1999) identified several measures taken by both the federal and state governments to boost science education at all levels. These included the payment of science allowance to science teachers, the establishment of universities of technology and special science schools, the policy of university admissions to reflect preference for the sciences (i.e. 60% of students to be in the science-based programmes), intensified training of science teachers and local production of science equipment. The question, however, is whether all these measures have yielded the desired results or are we better equipped today in teaching science than we were fifty years ago? The answer is definitely negative because all the efforts to advance science and technology education in the country appeared inadequate because of the continued existence of a myriad of problems militating against the teaching and learning of science.

One of the major recurring problems is the inadequacy of science apparatus used for laboratory practical activities in schools. The objective of teaching science in schools is to communicate the spirit of science and to ensure that students acquire the process skills of science. This cannot be effectively achieved unless students are exposed sufficiently to practical laboratory work. It is for this reason that improvements in the science curriculum in recent years have laid emphasis on laboratory activities and have even demanded a complete integration of both the theoretical and practical aspects of science teaching in schools. Furthermore, in order to ensure that science teachers teach with a particular purpose, many instructional materials have been written along this style. Unfortunately, several studies carried out over the years all indicate that many science teachers have failed to comply with this teaching strategy as a result of insufficiency of laboratory space and equipment in schools.

According to Ogunleye (1999), many secondary schools established over the years still remain without laboratories, while others have laboratories that are not sufficiently equipped. Even with the establishment of seven Development Centres under the National Agency for Science and Engineering Infrastructure (NASENI), the insufficiency of laboratory apparatus has not improved. The various centres are as follows:

- **Scientific Equipment Development Centres (SEDI) in Enugu and Minna** with the mandate to develop and produce scientific equipment and their production systems, and the ceding of these technologies to private sector satellite industries;
- **Centre for Adaptation of Technology (CAT), Awka,** with the mandate to develop and produce electronic devices and assemblies, computer technologies and their production systems, and the ceding of the technologies to private sector satellite industries;
- **Hydraulic Equipment Development Centre (HEDI), Kano,** with a mandate to develop and produce hydraulic and pneumatic machinery, materials, fittings, and their production systems and the ceding of the technologies to private sector industries;
- **Engineering Material Development Centre (EMDI), Akure**, with the mandate to develop and produce engineering materials and their production systems, and the ceding of the technologies to private sector satellite industries;
- **National Engineering Design and Development Centre (NEDDEC), Nnewi,** with a mandate to develop engineering design capacity in the country and dissemination of same to SMEs with a view to ensuring that Nigerian-made products attain standard specifications to make them globally acceptable; and
- **Power Equipment and Electrical Machines Development Centre (PEEMA|DEC), Okene**, with a mandate to develop and produce required hardware and accessories necessary for the efficient operation of power systems in the nation.

It is sad to remark that the situation of science equipment shortages in schools has not improved. The end result is that "many students learn science without laboratories and equipment" which is not in the spirit of science. Educators have suggested that education in science has three major aspects, as pointed out by Hodson (1993). These are:

(a) Learning Science (i.e. acquiring and developing conceptual and theoretical knowledge). For one to attain this goal, four major steps were suggested as follows:

(i) Identifying learners' ideas and views about what you want to teach.
(ii) Designing experiences to explore these ideas and views.
(iii) Providing stimuli for learners to develop and possibly change their ideas and views.
(i) (iv). Supporting learners' attempts to rethink and reconstruct their ideas and views.

(b) Learning about Science (i.e. developing an understanding of the nature and methods of science and an awareness of the complex interactions between science and society. This could possibly be achieved if teachers make the implicit explicit by going through the following procedure:

(i) carrying out investigations and explorations during which students are advised to reflect on their learning progress.

(ii) explaining the differences between theory and experiment to students.

(iii) (iii) encouraging students to undertake their own investigations using a wide range of active learning experiences such as simulations, role-play, dramatizing.

(iv) employing students to engage in language related activities such as reading and writing actual accounts of experimentation.

(c) Doing Science (i.e. engaging in and developing the expertise in scientific inquiry by using the methods and procedures of science to investigate phenomena and solve problems). The only effective way to learn science is by doing science alongside a skilled and experienced practitioner who can provide onthejob support, criticism and advice.

The main role of science education in primary and secondary schools should be to produce young scientists. The general belief among science educators and scientists is that practical work in science education increases comprehension of scientific principles and their application in the real world. Modern teaching methods in particular emphasize 'learning by doing' and hands-on approaches. For practical work in science teaching, some specialized equipment and facilities are needed, which are rarely available in many developing countries.

Practical Activities in Science Education

In recent times, laboratory practical work has become widely accepted as an integral part of science education. Today, practical work can be regarded as one of the distinctive features of science education and one on which an enormous amount of time and money is invested by virtually all governments of the world. This is because it is one of the great expectations of students learning. According to Millan et al (1999), practical work can be defined as:

> all those kinds of learning activities in school which involve students at some point in time handling or observing real objects or materials they are studying (or direct representation of these in a simulation or video recording).

From this definition, it is evident that practical work can help students to build bridges between the domain of real objectives/observable things and the domain of ideas. Practical activities at different levels of sophistication are today present in the majority of school science curricula in Nigeria, at both the primary and particularly the lower and upper secondary school levels. Practical activities usually require special facilities and equipment. The term 'equipment', as used in this paper, covers all the support material for science teaching, which include perishable items (e.g. glassware) and consumables (e.g. chemicals).

In many countries, science education is suffering from a dearth of appropriate apparatus and equipment. To improve the situation, many national, regional and international projects have been launched, emphasizing the development and production of science equipment and kits. However, their success was in many cases far below the expected. The World Bank, for example, has supported secondary school science in over 100 projects. In the Bank’s evaluations, almost half of the outcomes were assessed to be negative. Other World Bank projects, which were successful from the equipment acquisition and distribution point of view, were found not to improve the quality of science education substantially. In some cases the equipment provided was not used at all. There were many possible reasons for projects supplied with equipment to fail. Some of these are listed below:

- The equipment does not suit the existing curriculum used in schools.
- Training was not provided for teachers and laboratory technicians.
- Sophisticated equipment provided was not always comprehensible to students.
- Equipment was unevenly distributed to schools.
- The production cost of the equipment was high.
- There was inadequate supply of consumable materials, maintenance, repair and replenishment.

Problem of Study

One of the approaches to overcome these problems in supply, maintenance and use of equipment for science education in this project is the development of **low-cost** and **locally produced science**

equipment and kits. Local production of equipment for science education, particularly at a low cost might provide an opportunity to change the situation. Its main benefits, as seen by many educators include:

1. lower cost,
2. easier maintenance and repair,
3. better availability of spare parts,
4. higher relevance to the curriculum,
5. higher local content,
6. contributions to self-reliance, and
7. flexible adaptation for new topics in the curriculum.

In addition, lower cost experiments with equal or even higher educational value could also be often developed. There are different approaches to the supply of locally produced equipment in different countries of the world. Possibilities include:

1. production by teachers and students,
2. establishment of central production units in the country,
3. central development and assembly of equipment and kits,
4. decentralized development and production, and
5. a combined approach (probably the most frequent).

We have adopted the fourth model in this research project.

The project therefore has the following objectives:

1. To improve science education by developing prototypes of equipment, materials and kits which could be produced economically within the country, for the teaching of science.
2. To develop reliable, low-cost and locally produced science apparatus and kits that are easy to fabricate and easy to maintain.
3. To describe experiments compatible with such apparatus and kits that illustrate the concepts and practice of modern science.
4. To transfer the know-how to teachers through hands-on workshops, manuals and videotapes.
5. To set up a production centre at the University of Lagos that will be able to manufacture improvised science apparatus and science kits, and also assemble various types of science equipment that could be used in schools.
6. To develop re-packing facilities for mass production and assist in establishing a marketing and distribution network to schools.

Method

Development of prototypes

Work on designing and developing from locally available materials low-cost prototypes covering a broad range of some of the equipment used at the secondary school level was undertaken in the fields of biology, chemistry and physics for the practical activities listed in the new secondary school curriculum. The method used involved the actual construction of some apparatus for the teaching of physics, chemistry and biology in schools. The details of construction for each of the equipment are as follows:

Specifications of the improvised science apparatus kits

1. **Electricity experiment kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 32.5 x 20.5 x 21.5 cm.

List of apparatus: Wheatstone bridge (109 x 8.5 x 2 cm), Resistance box, Lead acid accumulator (2.o volts), One-way key (10.4 x 6.3 x1 cm), Jokey (8 x 0.7 x 0.7cm) and Galvanometer.

2. **Electromagnetic Induction experiment kit**

The kit is made of wood lined with leather and cloth both internally and externally with dimensions of 41 x 23.3 x 29 cm.

List of apparatus: An improvised alternating current generator and Galvanometer.

3. **Coefficient of friction / Moment of inertial experiments kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 43 x 16 x 10 cm.

List of apparatus: Inclined Plane (66 x 7.5 x 2 cm), Pulley wheel, Trolley, Known masses, Scale pan.

4. **Hooke's law and simple harmonic motion experiments kit**

The kit is made of mild steel sheet coated with grey colour externally and foam internally. The dimensions of the kit are 34 x 32.5 x 7.5 cm.

List of apparatus: The apparatus consists of a 39cm long scale that is mounted on a simple stand and base, a spring with a weight hanger and attached pointer.

5. **Optics experiment kit**

The kit is made of mild steel sheet, and is metal coated with grey colour externally and foam internally. The dimensions of the kit are 33.5 x 23.5 x 10.3 cm.

List of apparatus: Optical bench, **lens** holder, pin holder, screen, convex lens, pin.

6. **Titration experiment kit (Chemistry)**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 58 x 15 x 13 cm.

List of apparatus: Pipette, Burette, Conical flask, test tube, beaker, volumetric flask/standard flask, retort stand, clamp and boss head.

7. **Soil sample collection apparatus kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 51.5 x 16 x 13 cm.

List of apparatus: Soil Auger (Ø 8.8 cm x 22.5 cm), Handle (Ø 2.5 x 29.8cm) and two extension pipes (Ø 2.5 x 45.5cm)

8. **Water transparency and turbidity experiment kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 23.5 x 23.5 x 11 cm.

List of apparatus: Secchi disk [It consists of Ø 20 cm Mild steel x 8 mm in thickness, 14 cm square steel plate, eye bolt (M12 x 40mm), two flat washers, one locking washer, two nuts (M12), and nylon rope.]

9. **Underwater sample collection kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 36 x 22 x 22.5 cm.

List of apparatus: Grab and two detachable handles

10. **Microbiological Analysis of Samples Kit**

The kit is made of mild steel sheet metal coated with grey colour externally and foam internally. The dimensions of the kit are 43 x 16 x 10 cm.

List of apparatus: Magnified lens, Spirit lamp

Quality Control Mechanism

The researchers were very much concerned with the quality control of the science equipment produced. Hence every item had to be checked against the standards laid down for each component and for the functionality of each item. The work involved was laborious and the task daunting. Items of equipment for science areas were tested. The test consisted of a laboratory and a field test.

Results

The final results of the various fabricated designed kits are as shown in the various diagrams as indicated in Figure 1 with 0.01 degree of accuracy. Each apparatus was packaged in its aluminum containers. Various experiments were performed in the classroom with the various kits. The results as calculated agree with theoretical values as given in various physics textbooks with accuracy of ±1 experimental errors.
The project is currently on-going for further refinement, robustness and portability. The beauty of the improvised apparatus is that parents can easily purchase them for their children and these can be taken home for students to carry out various laboratory practical activities at home on their own. Table 1 shows details of the Name of Kit, list of Apparatus and the local cost of producing each of the science apparatus kits as compared with their market prices.

Table 1: Cost of Improvised Science Apparatus Kits as Compared with their Market Prices

S/N	Name of Kit	List of Apparatus	Production Price	Market Price
1.	Electricity experiment	Wheatstone bridge, Resistance box, Lead acid accumulator, One-way key, Jokey, Galvanometer and kit.	₦16,000	₦260,000
2.	Electromagnetic Induction experiment	An improvised alternating current generator, Galvanometer and kit	₦12,000	₦100,000
3.	Coefficient of friction / Moment of inertial experiments	Inclined Plane, Pulley wheel, Trolley, Known masses, Scale pan.	₦10,000	₦120,000
4.	Hooke’s law and simple harmonic motion experiments	39cm long scale that is mounted on a simple stand and base, a spring with a weight hanger and attached pointer	₦10,000	₦160,000
5.	Optics experiment	Optical bench, lens holder, pin holder, screen, convex lens, pin	₦10,000	₦100,000
6.	Titration experiment	Pipette, Burette, Conical flask, test tube, beaker, volumetric flask/standard flask, retort stand, clamp and boss head	₦18,000	₦180,000
7.	Soil sample collection	Soil Auger, Handle and two extension pipes.	₦21,000	₦190,000
8.	Water transparency and turbidity experiment	Secchi disk and nylon rope	₦15,000	₦160,000
9.	Underwater sample collection	Grab and two detachable handles	₦20,000	₦140,000
10.	Microbiological Analysis of Samples	Magnified lens, Spirit lamp	₦47,730	₦94,000

The second stage will consist of developing materials for students' study guides, which will integrate text and instructions for carrying out experiments and exercises to consolidate the experiences. Furthermore, teachers' guides will also be developed which will give detailed instructions for the teachers to follow when students are performing experiments.

The third stage of this project will encompass the production of all the science apparatus and kits needed for carrying out the experiments and practical work that have been described in the secondary school curriculum. Furthermore, kits will be designed for use in the classroom to carry out a limited number of hazardous demonstration experiments.. The third phase of the project will also seek to address the very difficult problems of maintenance and care of materials after use.

Conclusion

Experiences from many developing countries demonstrate that the quality of science education is often unsatisfactory, especially with respect to the use of equipment which is imported thereby draining their limited foreign currency, without an apparent positive effect. What can be concluded from this research project therefore is that as a nation we need to be self-reliant especially in the development and manufacture of science education equipment and kits. The Federal Government of Nigeria and all the other State governments should therefore encourage the establishment and development of small-scale enterprises in the area of equipment manufacture. If the equipment is also low-cost, then it is more likely to be used in the classroom. Local experts in the country should be encouraged to develop their talents when decisions about new equipment for science education are to be made. Design of low-cost equipment has certain distinct educational advantages, particularly if it employs local materials, which are familiar to the students. Hence, scientific concepts and their relation to the real world can better be understood and demonstrated, when familiar materials and contexts are used.

Much has been achieved but much still remains to be done if our primary and secondary schools are to reap the full benefits from this Project’s activities in science equipment development, production and distribution. The project needs to be continued, so as to develop and improve the availability of school science equipment and indeed, to extend its work to post-secondary institutions.

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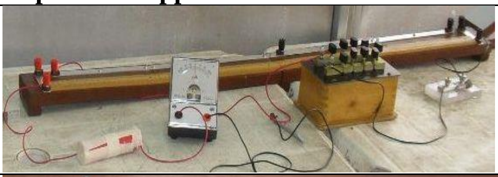
Diagrams of the Various Fabricated Improvised Apparatus and Their Casings

S/N	Improvised Apparatus	Casing for Improvised Apparatus
1.		
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