

AFRICAN EDITION

Training of Trainers in Science and Technology Education



Commonwealth Secretariat

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Education Department
Human Resource Development Division
Commonwealth Secretariat
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Preface

Many developing countries are striving to provide quality science, technology and mathematics education (STME) as part of basic education in a context of limited resources. The Commonwealth Secretariat's work in STME is in four main areas: training of trainers; scientific and technological literacy for all; measures to enhance the participation of girls and women in science and technology; and training of laboratory technicians.

Efforts to improve STME through better quality pre-service and in-service teacher education have often neglected the needs of those who are providing training at universities and colleges of education. In order to address this issue the Commonwealth Secretariat organised in the UK a planning meeting of science, technology and mathematics educators from Commonwealth countries. The participants at this meeting recommended the development of monographs to assist teacher educators in the delivery of science, technology and mathematics teacher education programmes. The basic framework of the monographs was also developed in this meeting.

The draft monographs were produced by practising African science educators in a workshop organised in Nigeria, and were reviewed in an international conference in Botswana organised by the Commonwealth Association of Science Technology and Mathematics Educators (CASTME). They were then revised, on the basis of the comments received from the reviewers, by a team of African science educators in a workshop held in South Africa.

On behalf of the Commonwealth Secretariat, I wish to express gratitude to all the participants who have contributed to the development of these monographs. I am also thankful to CASTME for arranging the review of these monographs during their Botswana International Conference. I also wish to express my sincere gratitude to The Rockefeller Foundation and Primary Science Programme, South Africa, for co-sponsoring the workshops in Nigeria and South Africa respectively. Last but not the least I wish to thank my ex-colleague, Professor Sam Bajah, who initiated this project and the development of the drafts, and Dr Ved Goel who accomplished the revision of the monographs and their editing into their present form.

We are fully cognizant of the fact that these monographs have not been tested in the field prior to printing. I therefore sincerely request the science and technology educators in Africa to try out the monographs and send us their evaluations and suggestions for further improvement.

Professor Stephen A Matlin
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Introduction

An important aspect of science education reform in the world today is the implementation of science and technology education. Technology bridges science and society, brings relevance to science teaching, and unifies different subjects. It provides approaches to problem solving, relates different subjects to life and helps to link theory and practice. The science teacher educators in many developing countries are finding it difficult to prepare science teachers for this kind of science education. They recommended in a Commonwealth Secretariat meeting that monographs be developed which could guide science teacher educators in their attempt to prepare science teachers for science and technology education. These monographs have been developed to meet that felt need of science and technology teacher educators.

Science graduate programmes in the Universities have long been organised in terms of separate subjects namely botany, chemistry, physics, zoology etc. Consequently the scope of science knowledge of most science teacher educators is limited- they are familiar with one or two science subjects. However science and technology education usually involves inter-subject teaching. This requires teacher educators to have a broad base of science knowledge. In Monograph 1 '**Training needs of science and technology educators**', it has therefore been highlighted that while recruiting teacher educators, candidates with broad-base knowledge of science subjects be preferred. Selected candidates and existing teacher educators who lack breadth in their science knowledge be provided opportunities to acquire the perceived deficiencies through in-service courses or attachments with science departments in universities/colleges.

It has also been recognised that most science teacher have tended to stress science while neglecting technology in their classes because of lack of training in linking technology with science. The priority task is therefore to improve the pedagogical skills of science teacher educators themselves such that they could relate science and technology using examples of local technology. This also requires that teacher educators' will be able to help teacher trainees to think in many different ways, including the selection of methods and the use of different materials and tools. Science teacher educators must provide this kind of experience to the teacher trainees during the courses they conduct for science teachers. In Monograph 2 '**Teaching practice for science and technology**', a two-tier approach to the training of science teachers has been suggested whereby the science teacher educator first demonstrates the use of a pedagogy followed up with practice by the prospective teachers. Considerable emphasis has therefore been laid on practice teaching and its supervision.

Effective science and technology education requires the use of variety of resources. Lack of availability of material resources specially the science equipment has been regarded as an impediment in providing quality science and technology education. Many science teacher educators fail to recognise the use of locally available and improvised materials as an opportunity to provide relevant and life related science and technology education. The reason for this cynicism partly lies in the lack of their ability to identify, use and improvise suitable locally available materials. Monograph 3 '**Resources in science and technology education**' has therefore been written to help teacher educators' first in the identification and use of locally available material and how they can go about improvising such materials in their own teaching. Secondly, it helps them to provide guidelines to teacher trainees in the use of such resources.

An important feature of the monographs is that they not only provide guidelines to the teacher educators to improve their own teaching but also provide strategies which could be used by them with their trainees to make them better science and technology teachers. Another common thread throughout the monographs is the emphasis on the regular use of those methods, materials and approaches by the teacher educators in their own teaching which they expect teachers to use. It is based on the understanding that when the trainees observe a skill in action, and get the opportunity to practice that after observation, the chances of transfer of skill improve.

Science teacher educators require tools and techniques to assess teacher trainees both at the formative and summative levels. They also have to provide training to the prospective teachers in evaluation to enable them to evaluate their students. Monograph 4, '**Evaluation**' precisely does this by discussing purposes, uses and techniques of different kinds of evaluation.

To improve the training of science and technology teachers in the teacher training institutions, and the delivery of science and technology education in schools requires coordination at all levels. Monograph 5, '**Coordination in science and technology education**', discusses the important interactive relationships within and across teacher training institutions, schools and external institutions and provides guidelines on achieving such a relationship. Monograph 6, '**Participating in science and technology education research**' has been written to stimulate action research amongst teacher educators and demonstrates how they could generate such research among teachers.

MONOGRAPH 1

The training needs of science and technology teacher educators

1.1 Overview

In most developing countries the provision of a good basic education is a matter of great concern. High quality science and technology education depends on effective and efficient training of teachers. This in turn depends on the quality of the teacher educators. At present, there is little comprehensive information available about the academic and professional qualifications of science and technology teacher educators, or about their responsibilities and training needs. The best intentions for improving teacher education will fail unless attention is paid to improving the quality of science and technology teacher educators.

1.2 Objectives

The objectives of this monograph are to help policy makers and administrators, responsible for the recruitment and training of science and technology teacher educators, by:

- identifying the professional and academic qualifications and training needs of science and technology teacher educators;
- considering ways of improving the qualifications of science and technology teacher educators and of enabling them to keep abreast of developments in their fields.

1.3 Recruitment and training

The recruitment process normally involves some form of advertisement seeking applications, followed by short-listing of candidates against established criteria, and selection based on performance in oral interviews.

The ideal candidate for a science and technology teacher educator post would usually need to meet the following criteria:

- Possession of an appropriate professional qualification, such as BEd or a Post-Graduate Certificate in Education (preferably directed at primary or basic education),

and, ideally, an MEd qualification. Relevant teaching experience at the appropriate level would be a specific advantage. (A candidate with secondary experience would need to show evidence of some clear interest, involvement or willingness to gain direct experience of work at the primary level of science and technology education.) Three to five years of primary teaching experience is the usual basic requirement.

- Academic qualifications indicating a broad basic grounding in science and technology, including, ideally, a first degree in a science-related area or equivalent qualifications in technology. Candidates who lack breadth in their academic qualifications would need to indicate a willingness to remedy such shortcomings within a given time.
- Evidence of involvement with, and active participation (including extra-mural activities) in, a relevant professional organisation, such as the following, would be an advantage:
 - Science Teachers’ Association of Nigeria (STAN)
 - Ghana Association of Science Teachers (GAST)
 - Southern Africa Association for the Advancement and Research in Maths and Science Education (SAARMSE)
 - Namibian Association of Science Teachers (NAST).
- Possibly some indication of research interests, or evidence of a capacity for, or commitment to, research in science and technology education through academic, professional or popular writing.
- Reliable testimonials and confidential referees’ reports.

At the short-listing stage, due consideration needs to be given to gender equality. In many countries, science and technology education departments in colleges and universities are dominated by men. These countries should make deliberate attempts to identify suitable women candidates. Women science and technology teacher educators not only bring a different perspective to the training of teachers, but can provide teachers with strategies for promoting participation by girls in science and technology.

At interview stage, the extent to which short-listed candidates meet the following criteria can be assessed:

- Positive attitude towards science and technology education, including the gender perspective, and keeping abreast of current developments in science and technology education.

- Potential ability to adapt to, and understand, the contextual needs of the specific institution and the community it serves.

The teaching ability of candidates might be compared by requiring them to present a prepared lesson, lecture or practical class to students. This emphasises that practical teaching ability is as important as paper qualifications and skilful interview technique.

Unless a country is already well supplied with candidates meeting these criteria for science and technology teacher educator posts, appropriate training will need to be provided to make up the short-fall. The selection process involved in recruitment will indicate clearly what the general and individual training needs are and how they might be met through in-service training courses.

1.4 Career paths

Criteria for promotion of science and technology teacher educators, as for other academic staff, usually include:

- A satisfactory period of service – normally two to three years after appointment.
- Evidence of a research interest in science and technology education, through the presentation of a case study or research papers to peers, or through publications.
- Evidence of administrative capability and leadership skills.
- Satisfactory Head of Department's assessment report and recommendation.
- Evidence of involvement, with local and regional science and technology teachers, in ongoing professional support and development, as well as a commitment to professional development of colleagues.

1.5 Academic and professional needs and responsibilities

In order to improve the quality of science and technology education at the basic level we need to meet the academic and professional needs and responsibilities of science and technology teacher educators. The quality of science and technology teachers depends on the availability of

science and technology teacher educators with sufficient grasp of the challenge and complexity of introducing young learners to the basics of these disciplines in a holistic and integrated way.

Currently, there are no courses that specifically train such teacher educators. In the short term, quality In-Service Education and Training (INSET) for science and technology teacher educators will be required. In the long term, a clear route will need to be developed to enable potential science and technology teacher educators to gain the academic and professional qualifications they need. Their **academic** needs may include updating on knowledge of subject matter and content. Their **professional** needs include an understanding of and confidence in the use of subject-specific pedagogical skills, together with an understanding of appropriate methods for science and technology education research.

These specific requirements exist within the wider **context** which will include gender issues, ethical and humanistic issues in science and technology, cultural awareness, communication skills and liberal and African studies. The academic and professional needs interact with one another as well as with the context, as shown in Figure 1.

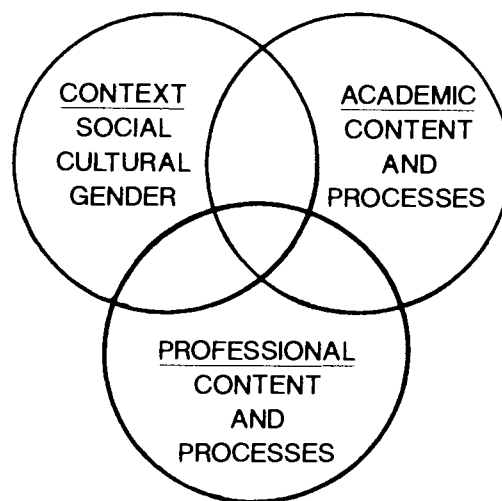


Figure 1: The interactive nature of the areas of training

Table 1 summarises the broad training needs of science and technology teacher educators and indicates where subsequent training might be required for individuals with identified professional or academic shortcomings.

Table 1: Academic and professional needs of science and technology teacher educators					
ACADEMIC		PROFESSIONAL		CONTEXT	
Science and technology subject knowledge	Science processes	Education studies	Subject-specific pedagogical skills	Curriculum studies	Manpower development studies
	Observation. Classification. Experimentation etc.	Educational psychology. Philosophy of education. Sociology of education.	Teaching methods. Micro-teaching. Teaching practice.	Science and technology education research. Materials development.	General liberal studies. Cultural/community awareness. Communication (language skills, etc.)

Science and technology teacher educators will have to develop competence in their trainees across the whole breadth of science (biology, chemistry, physics, earth science) and technology, including coverage of all the areas that the teacher will have to teach. They need to:

- be able to demonstrate the investigative and problem-solving approach to science and technology;
- be able to present examples of open-ended investigations and how to report them scientifically;
- encourage trainee teachers to generate their own investigations and follow them through, so that they in turn learn how to support and encourage their pupils in the same processes at their own levels;
- be able to demonstrate the significance of classroom skills in relation to real-life problems;
- be up-to-date with current learning theory, such as the recognition that different children build up knowledge in different ways.

1.5.1 Academic responsibilities

Science and technology teacher educators usually have the following responsibilities:

- **Teaching.** To organise, implement, and critically evaluate the content of science and technology curricula and appropriate teaching methods.
- **Practice teaching.** To support student teachers in teaching practice (see Monograph 2).
- **Research.** To design, plan, conduct, and publish research.
- **Evaluation.** To carry out continuous review of existing programmes and the diagnostic and formative assessment of students' academic attainment and progress.

- **Record keeping.** To keep accurate records of examination results, nominal rolls, laboratory stock, workshop materials, etc.

It is important for science and technology teacher educators to be academically well prepared and equipped to meet the demands made of them. They should be familiar with the subject matter and content of the curriculum. They should understand how science and technology, their philosophical foundations and sociological aspects, are interrelated. This is important, because problems in science and technology tend to require skills and knowledge that are cross-disciplinary in nature and best handled by team-teaching. Science and technology teacher educators also need to have a basic knowledge of everyday applications of science and technology, their social implications and how the concepts and processes are used in industry and commerce.

Administrators can encourage teacher educators to take up research by:

- making research opportunities available;
- offering grants;
- facilitating attendance at conferences;
- organising in-service training in research methods and report-writing and providing professional support at different levels of research;
- communicating research findings through newsletters or journals.

1.5.2 Professional responsibilities

The science and technology teacher educator needs to possess pedagogical knowledge, both of concepts and procedures, and to be able to pass this on to pre-service students and in-service teachers to improve their general effectiveness in the classroom. They therefore need to develop competence in the following areas:

- **Pedagogical skills.** These are the conceptual knowledge and procedural skills needed to enable teacher educators and teachers to bring about effective learning. They include selection and use of appropriate teaching strategies for particular objectives, class sizes, available materials, learning environments, etc. They also include the ability to guide students in reflecting on their teaching and to encourage their involvement in the teaching–learning process.
- **Supervisory, guidance and counselling techniques.** The science and technology teacher educator needs to develop skills in classroom observation, guidance and counselling of students on academic and professional matters, including supervision of teaching practice or during ‘micro-teaching’ (see 2.6) sessions.

- **Social and psychological considerations.** Understanding the social and psychological characteristics of prospective science and technology teachers and pupils at basic education level, and providing guidance to prospective teachers on how to deal with them. Understanding gender issues in science and technology education and the strategies to deal with them.
- **Curriculum development.** Constructing curriculum materials and teaching–learning aids.
- **Research.** Carrying out ‘action research’ (see 6.6) and other types of research in education, which can contribute to understanding the needs of the pupil, the classroom and the school in general.

There is currently an imbalance in the practice of these academic and professional responsibilities. Science and technology teacher educators need to put themselves in the place of teachers, attend seminars and spend time actually working in schools. This will make their own teaching much more realistic and effective, because it will be based on real classroom experience.

1.6 Strategies for ongoing professional development

Science and technology teacher educators need support, throughout their teaching careers, to develop both academically and professionally. In the *Final Report of the International Forum on Scientific and Technological Literacy for All* (UNESCO, 1993), it was stated that such support should include:

- partnerships between the world of production and the community, which would allow teacher educators to be exposed to the latest technology and also increase society’s commitment to science and technology teacher education programmes;
- updating appropriate teaching/learning instructional materials, facilities and equipment;
- updating of teaching skills, knowledge of learners and content;
- induction programmes for beginning teacher educators;
- assistance in developing leadership skills;
- salary structures attractive enough to recruit and retain the best teacher educators;
- adequate reward for teacher educators for those activities which are related to maintenance of their continued involvement with teaching as a dynamic profession.

These measures can be realised through:

- in-service education programmes organised by universities, colleges of education, subject associations and employing authorities (i.e. Ministries and Departments of Education);
- formal links, including visits and attachments, with industry;
- teaching at the school level and carrying out action research with science and technology teachers;
- provision of resources by governments, including improved salary conditions;
- joining professional organisations;
- corresponding with other professional science and technology teacher educators.

1.6.1 Types of INSET programmes

In-Service Education and Training (INSET) is essential for updating the knowledge and improving the professional competence of science and technology teacher educators and teachers. At present, there are no regular INSET programmes specifically designed for science and technology teacher educators. Provision should focus on development needs, current issues and policy matters, as well as training and certification needs. The following are suggestions for types of INSET programmes.

Issue-based INSET

- **Workshops.** Hands-on activities designed to cater for specific professional development in terms of knowledge and skills.
- **Seminars.** Discussion – usually of short duration – of academic and/or professional issues and problems. They normally consist of talks or presentations followed by discussion, often in small groups. There should also be opportunity for plenary, summary discussion.

Certification-based INSET

- **Sandwich courses.** These can be organised by colleges of education, universities and polytechnics during long vacations to upgrade science and technology teacher educators professionally. Periods of normal teaching are alternated with short periods of full-time attendance at local colleges. Sandwich courses can be supplemented by distance-learning modules or specific practical projects or tasks (action research). Follow-up field visits by course co-ordinators contribute to the effectiveness of sandwich courses.
- **Study courses.** Science and technology teacher educators are granted full-time study leave in order to attend courses leading to a qualification. Such courses are INSET in the sense that a serving teacher educator breaks service to study. This is a means by

which underqualified teacher educators can obtain qualifications and qualified teacher educators can upgrade qualifications.

- **Distance-learning courses.** Structured learning modules are made available to students through a variety of media. There is minimal contact with tutors, and the student does not need to obtain study leave to be able to participate. Professional elements such as teaching practice are assessed by specially designated local personnel.

Institution-based INSET

- **In-college activities and meetings.** Organised by college departments, these enable science and technology teacher educators to exchange ideas and experiences and thus improve the quality of their teaching.
- **Conferences.** These may be local or international. They usually involve presentations, by science and technology teacher educators, of innovative methods and examples of good practice in schools. They provide teacher educators with the opportunity to update themselves on the latest equipment and published materials for science and technology education. Such conferences are a very valuable resource for sharing problems and new ideas.

School-based INSET

It is important for science and technology teacher educators who have been in a post for some years, to be officially released for a period to update their teaching experience at the level for which they are training students. This gives them a better understanding of the needs, characteristics and aspirations of the teachers and pupils in schools, and encourages the teacher educators to see themselves first and foremost as educators rather than as subject specialists.

Peer-group INSET

Science and technology teacher educators meet together as equals to share their problems and success stories. They can develop learning materials during such meetings. These can be at least as effective as the traditional 'course' led by an 'expert'.

Visits

Science and technology teacher educators should be encouraged to visit industries and other science and technology-based establishments such as science museums to acquaint themselves with the applications of science and technology principles in daily life. Visits may be for a day or involve extended periods of attachment to an establishment.

1.6.2 Content of INSET programmes

INSET programmes for science and technology teacher educators should include consideration of:

- the needs of the community in which the teacher educators are likely to work and of ways of orienting science and technology towards community problems;
- the content and objectives of science and technology education at different levels;
- problem-solving techniques;
- gender issues and how they can be addressed;
- the use and maintenance of science equipment and a laboratory;
- learning science and technology in a second language;
- management, co-ordination and use of resources;
- hands-on activities which integrate science and technology;
- the cultures of scientific and technological enterprises; their values, attitudes, assumptions, organisational structures and limitations.

Table 2: Examples of INSET programmes for science and technology teacher educators

TYPE	ORGANISER	LENGTH	ACTIVITIES	OUTCOME
<i>Issue-based</i>				
Workshop	Professional association, educational agency, private organisation, Ministry of Education, college of education, polytechnic, university	Varies	Lectures, demonstrations, discussions, practicals	Improvement in professional and academic competence
Seminar	As in workshop	1–3 days	Lectures, demonstrations, discussions	As in workshop
<i>Certification-based</i>				
Sandwich courses (vacation courses)	College of education, polytechnic, university	2–10 long vacations of about 10 weeks each	Practicals, lectures, demonstrations	Undergraduate diploma
Study courses	College of education, polytechnic, university	1–2 academic years	Lectures, demonstrations, practicals	Undergraduate diploma
Distance learning	University	1–3 years	Self-instructional modules, with follow-up contact for lectures, demonstrations, discussions	Undergraduate diploma
<i>Institution-based</i>				
In-college activities and meetings	college of education	Usually not more than a day	Discussions, demonstrations	Exchanges of ideas, update of professional and academic knowledge
Conferences	Professional association, educational agency, university	1–5 days	Lectures, demonstrations, discussions, practicals	Exchanges of ideas, update of professional and academic knowledge

MONOGRAPH 2

Teaching practice for science and technology education

2.1 Overview

The quality of science and technology education in schools depends on the training of teachers which in turn depends upon the quality of teacher educators. However good the curriculum, its aims cannot be achieved if, through inadequate training, teachers lack the confidence to implement it. Practical teaching experience in the classroom is a vital part of teacher training.

Frequently, insufficient attention is paid to this aspect of teacher education. Teaching practice is often given low priority and only the minimum requirements met. For instance: Have the students carried out the required number of lessons? Have the supervision requirements been met? Have the statutory weeks of teaching practice been complied with? The net result is that teaching practice is seen merely as a set of regulations to be complied with rather than the most critical aspect of teacher education, where theory and academic content merge into practice.

In many instances, primary teacher education students avoid teaching science and technology lessons and fulfil the teaching practice requirements with what they perceive to be 'easier' or 'safer' options. Science and technology topics tend to be seen as difficult and complicated by students who lack confidence or background in the subjects. On the other hand, confident students sometimes teach topics in a mechanical way that does not always ensure real understanding.

Technology is most often ignored in teaching practice. Teacher educators must make a conscious effort to provide opportunities where technology can feature more prominently than is presently the case. Links between science and technology should be emphasised in conventional subject teaching, and where possible the technical applications of science should be incorporated. Technologies in the local environment should be considered as possible starting points for science and technology teaching.

2.2 Objectives

The main aim of this monograph is to provide guidelines for teacher educators in science and technology to enable them to:

- plan and implement practical teaching experience;
- design programmes for retraining/updating through in-service teacher education (INSET);
- devise strategies for teaching large classes in science and technology;
- effectively manage classrooms in science and technology;
- implement appropriate strategies for supervision.

2.3 Pre-service training of teachers

Many factors have to be taken into account when planning and implementing a pre-service teacher education programme for science and technology teachers.

2.3.1 Students' science background

The entry requirements and length of training for primary science teachers vary from country to country. In some, A-level GCE, or its equivalent, is the qualification required for admission to a primary teacher training college which gives one to three years of training. In other countries a first university degree is the minimum qualification for admission to a one-year teacher training course. A formal qualification in science is not usually required for admission to a primary teacher training course, in spite of the fact that most primary teachers are expected to teach all subjects including science. This has implications for teacher training programmes.

Teachers' lack of confidence in the subject matter results in them being unable to:

- understand the logical flow of ideas and translate them into meaningful classroom learning activities;
- ask questions which promote thinking and are based on the existing ideas of students;
- respond to students' questions.

Pre-service training courses, especially those of only one year's duration, may not be able to make up for trainees' deficiency in knowledge of subject matter. But such courses may help trainees to identify areas or topics in which they do feel confident, and to translate this subject matter into a logical sequence of learning activities including thought-provoking questions. They can then try these out in the classroom under the guidance of the teacher trainer or an

experienced teacher. This helps to build up their confidence. Future in-service training programmes can help to fill gaps in subject-matter knowledge.

To overcome trainees' lack of confidence in teaching science, it should be compulsory for every trainee to teach a certain number of science lessons during their teaching practice. These need to be supervised either by science and technology teacher educators themselves or by very experienced advisory or science teachers.

2.3.2 Resources

In many developing countries, lack of material resources is considered to be the main reason for the poor quality of science and technology education. It is true that there is a lack of suitable printed learning materials in the local language, based on the local cultural and physical environment, and this handicaps both teachers and learners. But a lack of scientific equipment in primary schools is not as great a problem as is often claimed. This does not imply that no scientific equipment is necessary to teach or learn primary science.

For primary science teaching, the immediate local environment provides a wealth of resource materials, with plants, animals, food, housing, clothing, tools, transport, soaps and detergents, gardens and ponds offering a rich variety. In addition, empty bottles, cans, bottle-tops, plastic and paper bags, and low-cost materials such as nails, moulding clay, balloons, pipes, straw and string, can all be used to improvise materials for teaching science.

Teachers will need specific guidance on identifying and using locally available materials, and on procuring, storing and maintaining science materials. Science and technology teacher educators must ensure that during their own teaching they:

- increasingly use material from the local environment;
- use improvised items made from local materials;
- give enough practice to the trainees in the identification and use of local materials;
- encourage all trainees to improvise;
- give tasks to teachers in which they learn to use simple mechanical tools;
- show enthusiasm in using local materials to help to develop a positive attitude among trainees towards use of local materials;
- make use of audio-visual materials and train teachers in the use and maintenance of materials available in schools.

2.3.3 Working environment

Another important consideration is the environment in which teaching and learning will take place. Teachers may work in remote rural areas, in hilly areas, in schools with large classes, in single-teacher schools and in schools without enough classrooms and storage space for science equipment. The training must take into account the prevailing conditions and the implications for teaching and learning.

The motivation of teachers depends to a large extent on their working environment. A teacher working in an urban school may have lots of material resources but may face the problem of overcrowded classes. On the other hand, a teacher in a rural school may have fewer students to a class but be the only teacher in the school, and have to teach all grades.

Many teacher training institutions are insensitive to the range of environments in which teachers work. Training tends to be geared to an 'ideal' school environment. As a result, many teachers do not find the training very helpful. Science and technology teacher educators should therefore:

- Familiarise themselves with the variety of school situations in which teachers will work after their training.
- Discuss and demonstrate a variety of teaching methods which can be employed in different situations. Trainees then need to practise these methods in real school situations. They need to learn classroom management techniques, involving management of the curriculum, human and material resources in different working environments. Some management strategies which have been found useful in dealing with large classes and multi-grade situations are:
 - the use of class monitors;
 - senior students supervising the work of juniors;
 - group work;
 - use of printed learning materials such as work cards and supplementary readers;
 - the activity method.

2.3.4 Curriculum

The nature of the science and technology curriculum and the associated philosophy of teaching is another important area to be considered in planning a teacher training programme. While one curriculum may emphasise science content, others may encourage problem-solving and thinking on the part of learners or lead to a recitation of facts from textbooks.

The pre-service training of science and technology teachers cannot be limited to the curriculum currently being followed in a country or a state. Pre-service training has to be much broader and must consider a variety of methods which could be employed in science and technology teaching. The teacher educators must develop the following skills and competencies amongst the trainees:

- Relating methods, materials and teaching aids to the defined objectives. An activity approach may be too time-consuming if the objective is to pass on knowledge. Similarly, if the objective is to teach science processes, the lecture method is inappropriate.
- Asking questions which can be answered by using the materials at hand.
- Integrating subject matter and skills into a teaching–learning strategy.
- Use of process skills and understanding how they may be developed in children.
- Building on children’s existing ideas and thought processes to develop scientific ideas and ways of thinking.
- Being aware of, and using scientific knowledge to correct, the many false beliefs and superstitions which children often bring with them to class.
- Relating science and technology to agriculture, health, industry, nutrition and other aspects of real life.
- Using real-life learning experiences from the local environment to develop scientific ideas.
- Using local technologies to build scientific ideas and skills.
- Developing formative and summative evaluation skills.

The trainees need to be introduced to the large number of methods and techniques which can be used to achieve teaching goals. Science and technology teacher educators must explain that a particular method may be suitable for one teacher in a particular situation but not in another, and provide opportunities for the trainees to practise these methods and techniques during their training.

2.3.5 Language

Language presents a particular problem in science teaching. In many countries science is taught in English in spite of the fact that it is not the first or even the second language of the students, while many other subjects, such as social studies and moral science, are taught in the local language. Even in countries where science is taught in the local language, there are sometimes no local words for particular scientific ideas and terms. This problem needs to be considered during the training of teachers.

A Namibian primary school head teacher, who is also a science teacher, recently said: *'My biggest problem with science teaching is the language. We have the policy of teaching science in English. Children do not have a good command of the English language because it is not even the local language, let alone the mother tongue. Most of my time in science class is spent in teaching English.'* He added that the situation is worse with teachers who themselves do not have a good command of English language.

In countries where this is a real problem, science and technology teacher educators should advise teachers to explain scientific ideas in the local language or the language most familiar to students. Teachers should be trained to speak slowly in simple sentences, to use a variety of ways of communicating ideas, such as graphs, drawings and modelling, and to wait longer for students to respond to their questions. This requires patience and practice.

2.4 Teaching practice for retraining and updating

2.4.1 Need for INSET in science and technology

Many practising teachers with responsibilities for science and technology do not have recognised science and technology qualifications or experience. They require some form of in-service support and assistance if they are to be held accountable for the quality of science and technology education in their classrooms. Other teachers have taught aspects of science and technology as isolated subjects or have only been exposed to outdated methods of teaching it. They will not be able to make the links and appreciate the connections between science and technology components. Thus the In-Service Education and Training (INSET) programmes in science and technology are organised for:

- meeting the subject-matter deficiencies of teachers;
- introducing active-learning approaches;
- helping the teachers gain qualifications;
- implementing a new curriculum which requires additional skills related to methodology, classroom management and assessment;
- the professional advancement of teachers.

2.4.2 INSET strategies

Direct experience of teaching practice should be the focus of teacher development programmes. Practical experience of formulating tasks, accessing and mastering content, planning, preparing and then testing out science and technology teaching approaches in realistic settings is the only sure means to ensure that teachers will develop the confidence to adopt, adapt, implement and

appraise new ideas or approaches. It is essential that science and technology teacher educators responsible for INSET provision are sensitive to and committed to such experience/practice-led approaches.

The approach suggested here is that during the pre-service and in-service training, teachers experience the kind of science and technology teaching which they will be expected to practise themselves in schools. This implies that teacher educators must create situations in which teachers experience at their own level problems which they have to investigate. Teacher educators should respond to the questions of teachers as though they were teachers responding to the questions of pupils in schools, and help them solve problems in a similar way. This approach should enable teachers to achieve a better understanding of the joys and frustrations of children in the classroom.

Having experienced problem-solving at their own level, teachers should then be helped to formulate curriculum-based questions and problems for the students to try out with children in schools. It is essential that science and technology teacher educators responsible for INSET are committed to this two-tier empirical approach.

INSET programmes should respond to the 'felt needs' of teachers regarding their specific roles and responsibilities. It is therefore important for teacher educators to appraise the needs of teachers through discussion. Analysis of a new curriculum to find out the skills and competencies required to implement it may be useful. If teachers request help with a specific area of content, then this should be given in a practical way. The content falls into place for the teacher and is clarified when they carefully think through how it can be taught. It is important for the science and technology teacher educators to realise that one of the aspects of training where teachers need most help is in the skill of translating content into teaching/learning activities. This is achieved during teaching practice, and, if properly supervised by teacher educators, can avoid many of the problems of inappropriate science and technology teaching. INSET programmes are more productive when they focus on a practical approach that draws on theory and academic content.

In an INSET course teachers often expect teacher educators to do more than simply *tell* them what is required of them. They actually want to *see how* to do things. This may be achieved by means of a demonstration lesson or a video lesson. In either case, it should be followed up by practice sessions in real classroom settings, with feedback from the teacher educator.

One of the problems which teachers face is the lack of in-service support after initial training. Without encouragement and assistance when new approaches are being introduced, change is unlikely to be sustained. For this to happen, headteachers, school inspectors, education

officers and subject specialists all need to be included in training programmes, and their skills in classroom observation and providing feedback based on this observation also need to be enhanced.

Example of a pattern of INSET workshops – a South African NGO

At Primary Science Programme (PSP) Western Cape INSET workshops, we try to provide culturally sensitive and contextually responsive support and encouragement in an interactive and practical way. Teachers identify topics of concern at a mass planning meeting at the beginning of any year. Rotating panels of teachers participate in the specific planning of each cycle of workshops on a topic. Some teachers with special interests or abilities are invited to join in the presentation of the workshops.

In the workshops we review science content and draw together related background knowledge (usually based on a mind-mapping process). Collectively, we consider a range of different potential methodologies and approaches, with an emphasis on teaching science in a practical and relevant way. We try to ensure that the ideas co-developed in the workshops are tested in the reality of a classroom setting with as many as 60 or 70 pupils. Then we spend time collectively reflecting on the apparent outcomes that we observe. At the end of a cycle of workshops a booklet is produced that accurately documents the workshop process and these support materials are distributed to the workshop participants.

The content and ideas in a workshop report are not seen as final. Rather they are a record of a developing process which can always be improved upon, and often is, in that teachers tend to request a repetition of topics over a period of a year. Revisiting and refining topics is now seen to be a critical element of ongoing support.

2.5 Methods of teaching

2.5.1 Whole-class teaching

Whole-class teaching in a large class can be a stimulating and entertaining learning method, if it is carried out in an interesting manner by a teacher with good verbal and presentation skills. However, overuse with little feedback from students should be discouraged. Students lose concentration quickly, and a lesson should rarely be taught to the whole class for more than 30 minutes and even less for younger or less able students. Teacher educators should appreciate this and not often resort to whole-class teaching with their trainees.

Short spells of whole-class teaching may be useful for conveying instructions, for introducing a lesson, for passing on simple content and for summarising.

Whole-class teaching can be made interesting by introducing demonstrations. The teacher educator should explain that demonstrations can be used for a variety of purposes, such as illustrating process skills, safety procedures and sequencing, or reinforcing a concept that has been taught. Whenever demonstrations are used, teacher educators should encourage students to be involved in using the equipment, thereby ensuring better interactive learning. The teacher educator should also discuss where the teacher should stand during demonstrations, especially if they involve the use of apparatus. It may seem logical for the teacher to stand behind the apparatus and the students in front, but this can present the teacher with problems. For example:

- the apparatus is back to front for the teacher, with stands, clamps, etc., on the teacher's side, making handling more difficult;
- meters and other instruments that need to be read will be pointing towards the students.

Whilst the trainee teachers are likely to be quick to point out disadvantages associated with the teacher standing on the same side of the demonstration as the students, the teacher educator should discuss possible advantages of this method. The teacher can:

- see the apparatus from the same viewpoint as the students, who are at a distance from the demonstration, allowing a better overall view;
- move around easily;
- hold up part of the demonstration, or take it nearer to the students if they need a close-up view;
- have the same view as the class when guiding students in assisting with the demonstration.

Demonstrations can be very effective methods of learning, especially if participants are helped to focus on exactly what should be observed.

2.5.2 Problem-solving approach

In the problem-solving inquiry method, teachers facilitate learning rather than teaching directly, through:

- identifying phenomena and selecting materials that are rich in learning possibilities, and motivate students to pursue their own investigations;
- capitalising on students' curiosity;
- providing suitable materials that pose problems;
- asking challenging questions;
- using good judgement about when to interact with students and when or when not to hold whole-class discussion (not all students may have sufficient experience of the phenomena to contribute).

Use of the problem-solving inquiry method requires a good mastery of the subject matter by the teacher, who should at the same time be open to problems as they arise and be willing to learn along with the students. Much time needs to be spent after such activities on reviewing and evaluating the students' experiences in terms of the knowledge, process skills, attitudes and values acquired. Problem-solving inquiry methods of teaching should be given priority in science and technology education, even though they may be difficult to introduce with large classes. In such situations, classes can be broken up into groups and practical work arranged in the form of a 'circus' for the groups to move around. The groups can also be assigned investigative project work. Parents or assistant teachers could prove very helpful in supervising these groups.

An example of the problem-solving inquiry approach

Project to determine the best buy of fruit drink in terms of citric acid content

Basic information for students: All fruit drinks contain citric acid.

Whole-class session: Students brainstorm different ways to determine the citric acid content in fruit drinks.

Agree method: Titration with a base, e.g. NaOH solution.

Practical work: Students find out for themselves.

Pupils are given a problem to solve which is related to their own experience. For example, if you have to buy a piece of cloth to mop the kitchen tables which of the three given samples would you choose? Initially, all groups can do the same problem. Later, different groups can be involved in different problems at the same time, with parents or assistant teachers monitoring the groups.

It is important in the problem-solving inquiry approach that the teacher educator provides a situation where the learners are made to think, plan, execute using science processes and draw conclusions. Teacher trainees should be given many problems to solve at their own level, so that they come to appreciate fully the value of this approach. They should be helped to identify lots of problems which they can use with children.

2.5.3 Other valuable techniques

Many scientific ideas can be introduced with the help of games, toys, stories and models. Their appeal to children should be fully, but not excessively, exploited. For example, the game of push and pull can be used to introduce ideas related to force: which is easier to push or pull, the

greater or smaller force? Similarly, children could be given different boxes with one object in each and asked to predict what the objects are and what they are made of. An element of competition may also be introduced, but games must be simple and safe. There must be rules to be followed, with penalties for breaking them, and a clear learning objective for each game.

Toys are not teaching methods but are an invaluable resource to help develop scientific ideas. A simple bow and arrow can be used to develop ideas of elasticity, force, action and reaction, etc. Teachers should be encouraged to ask children to bring their own toys to school for possible use in learning situations.

Children like listening to stories: they stimulate interest and will often hold their attention. Stories should be short and have relevant content which provides the focus of the lesson.

Models are specially useful in science and technology since they put concepts which may be difficult for children to grasp into concrete form. They can also be used to demonstrate various working principles in a practical way.

2.6 Micro-teaching to develop teaching skills

Micro-teaching provides the opportunity for student teachers to practise specific teaching skills that they will need to become effective classroom teachers. It has the following characteristics:

- **Nature.** Micro-teaching is a teaching method in which the normal complexities of the classroom are reduced so that the teacher can practise the teaching of one specific skill at a time until it has been mastered. A number of separate experiences or skills are identified, isolated and practised.
- **Skill development.** Micro-teaching can be designed to help student teachers develop skills in areas such as: introducing a lesson, using questions, providing reinforcement, use of instructional materials, explaining concepts, giving directions, varying stimuli, class control and lesson closure.
- **Duration.** Each micro-teaching session should be between 5 and 10 minutes per student depending on the number of student teachers.

2.7 Classroom management

Instruction in classroom management in science and technology teaching should be about the effective and efficient utilisation of both the curriculum and the available human and material resources. This entails planning, organising, co-ordinating, delegating, monitoring and controlling the teaching/learning situation.

A considerable amount of time should be spent by the science and technology teacher educator on planning classroom activities (schemes of work, lesson plans and so on). Relevant resources should be organised for putting these plans into practice. For example, the apparatus or materials to be used need to be assembled, enough seating accommodation needs to be provided for all the groups, and decisions made on how groups are to be formed and who will be the group leaders. This should be practised in different working environments.

Close monitoring and control of the teaching/learning situation is essential. It is important for the science and technology teacher educator to move about the groups to ensure that everyone participates and to help resolve any problems which may arise. Delegation could include identifying group leaders/monitors (in schools this might include parents or assistant teachers) to supervise the work of the groups.

A strategy to overcome the burden of big classes was implemented by an innovative mathematics teacher in a Zimbabwean school

The teacher realised that pupils who experienced difficulty in mathematics were in need of individual help. Since it was not possible for the teacher to provide individual attention for all these children, the teacher appointed 10 pupils, who scored the highest marks in maths, as 'tutors'. The rest of the class was then evenly divided into 10 groups of more or less equal ability. The groups of pupils sat in circles with their tutors. The teacher introduced a topic and the pupils carried out problem-solving exercises. The tutors helped members of their groups with any difficulties.

This proved to be very effective:

- pupils in smaller groups were more inclined to ask questions, mention their problems, etc.;
- pupils who experienced difficulties with maths benefited from individual attention;
- tutors were themselves stimulated and enriched;
- the teacher's burden was lightened;
- the tutors eventually competed with each other, comparing 'their' groups' performances.

An approach well worth exploring.

Many teachers are unable to use active learning techniques because they lack classroom management skills. Science and technology teacher educators should therefore ensure that they provide enough opportunities for their trainees to practise these skills. Time needs to be spent on reviewing and evaluating the trainees' experiences to ensure that they have acquired the necessary classroom management skills, in different working environments.

2.8 Supervision of teaching practice in science and technology

2.8.1 Aims of supervision

Supervision of student teaching practice by science and technology teacher educators has two broad aims:

- To assess and evaluate the level at which the student teachers are able to apply science and technology teaching methods and procedures. In this context, supervision of teaching practice is an evaluative process.
- To provide both the teacher educators and the student teachers (pre-service and in-service) with opportunity to evaluate and reflect upon class teaching procedures and practice, to maximise learning in the situations prevailing in particular schools.

The supervisor and the student teacher should work out appropriate supervisory strategies for alternative procedures in the classroom. Thus, the supervision of student teaching practice becomes a reflective experience for both teacher educators and student teachers. It becomes an information-gathering process (a research process, if you like) which enhances and promotes growth in the competencies of all the participants.

2.8.2 Different strategies or models for supervision

Reflective collaborative supervision

This model emphasises close, reflective growth between supervisor and the student teacher, and involves four stages of development:

- **Pre-observation conferencing.** The supervisor and the student meet before the beginning of the lesson, to discuss the objectives of the lesson and other aspects of teaching procedures to be followed. The student teacher describes his/her proposed classroom procedures and the supervisor gives his/her reaction to them until agreement

is reached. The supervisor's observations are not predetermined but are based on the student teacher's suggested procedures.

- **Observation and teaching.** The supervisor observes the student teacher in action, following the agreed-upon teaching procedures, and records his/her observations with comments for further discussion during the post-observation conference.
- **Post-observation conferencing.** The teacher educator and the student exchange views on the observations, feelings, strengths and weaknesses of the procedures followed during the lesson. They then agree on alternative strategies/procedures.

The guiding principle in this phase is reflective evaluation of both the classroom procedures of the student teacher and the supervisory practice of the supervisor. For this purpose the supervisor needs to be accurate in recording his/her observations, highlighting only those procedures dealing with specific science and technology content and their methodological treatment as agreed upon during the pre-observation conference phase. A suitable pro-forma may be developed to record the observations.

- **Establishing alternative classroom procedures.** The supervisor and the student teacher draw up alternative classroom procedures as agreed upon during the post-observation conference. These are not prescriptions of 'good' procedures from the supervisor, but alternatives which should be tried out by the practising student teacher for subsequent observation. While these alternatives may be entirely new, they may have been tried out in different contexts elsewhere. In this instance, the student teacher and the supervisor would be adding the 'new' alternatives to their repertoire of science and technology teaching procedures for reflective evaluation in subsequent lessons.

This method of supervision gets the student teachers into the habit of seeking out new teaching procedures and promotes in supervisors the desire for reflective supervisory practices.

Possible constraints of the reflective collaborative supervision model

One inherent constraint of reflective collaborative supervision of student teaching is time. While the approach may work effectively in on-campus teaching practice settings, time constraints could prevent teacher educators from using this model in its entirety when teaching practice takes place in schools remote from teacher training institutions.

Instead, the following strategies could be tried:

- use of co-operating teachers as supervisors in the teaching practice schools (apprenticeship model);

- peer supervision;
- involvement of headteachers, education officers or subject specialists.

Using co-operating teacher supervisors (the apprenticeship model)

In this model, the teacher whose classes the student teacher takes over becomes the co-operating teacher supervisor, with the student teacher becoming his or her 'understudy'. The co-operating teacher sits in on all the lessons taught by the student teacher, following the procedure set out above for reflective collaborative consultation. The teacher educator supervises the student teacher on only a few occasions.

Practising teachers have to undergo a short period of training before they are certified as co-operating teacher supervisors. This system of supervision makes the schools partners in the initial training of the teachers and therefore makes them feel responsible for training the kind of science and technology teachers they would like to employ in their schools.

In order for this system to work the teachers' interest and enthusiasm in co-operating with the teacher educators must be sustained. This could be done by providing incentives for the co-operating teachers, such as:

- certificates as tokens of appreciation which could be considered for promotion purposes, earning exemptions for enrolling in teacher education programmes, etc.;
- recognition as teacher leaders in the running of INSET workshops, seminars, etc.;
- participation in the assessment and evaluation of science and technology education programmes;
- recognition as 'resource persons', visiting lecturers, etc.

Peer supervision

In peer supervision, with the agreement of the student teacher, his or her peers sit in during the lesson. If four or five student peers comment on and discuss the lesson presented, the learning process would be in line with the latest views on the 'socio-constructivist' learning approach.

A variation on this is 'buddy-teaching', also used in teaching practice, when two students are coupled for a period of time over the three-week practice teaching period. While one presents the lesson the other supervises, and vice versa.

MONOGRAPH 3

Resources for science and technology teaching and teacher training

3.1 Overview

A wide range of resources is available that science and technology teacher educators can use and introduce to their trainees to assist with the teaching and learning process. These include conventional things like tools, equipment and consumable supplies, printed materials and human resources. They also include locally available materials and technologies, thus linking what is being learnt in school with everyday life, and bringing relevance to the teaching of science and technology.

The science and technology teacher educator has two main responsibilities with regard to resource materials:

- to identify the resources needed for science and technology in the teacher education programme;
- to be fully conversant with the human and material resources which schools can utilise and the skills required by teachers to develop and use them effectively.

It is also important that the science and technology teacher educators use resources during training that are similar to those available in the schools or environments where their students are or will be teaching.

3.2 Objectives

The objectives of this monograph are:

- to identify resources that science and technology teacher educators might use;
- to outline strategies for making use of resources, especially those locally available, for teaching science and technology;
- to discuss issues relating to the use of resources in science and technology education.

3.3 General considerations in identification, selection and use of resources

Several factors must be considered when deciding what resources will be needed for teacher training. Decisions are guided by answers to questions such as:

- What investigations are anticipated?
- How will students be grouped?
- What resources may be needed to investigate problems and questions raised by student teachers?

The following are general criteria for the identification, selection and evaluation of resources:

- **Appropriateness.** Are the resources appropriate to the age group, to the teaching objectives, and in their subject content? Are printed materials at the appropriate reading and comprehension level?
- **Accuracy.** Is the content of the material accurate? Are there errors, biases, including gender biases, unwarranted conclusions?
- **Cost.** Does the outcome of use justify the cost in terms of money, time and effort?
- **Demand.** Does the material engage the thinking skills of learners? Does it demand creativity, problem-solving and a high degree of participation on the part of the student? Will the resource hold students' attention for a reasonable amount of time?
- **Comprehensiveness.** Does the material explore concepts etc. in enough depth and breadth? Does it allow learners to organise information as well as gather information? Do textbooks contain questions, advance organisers, illustrations, summaries, glossaries?
- **Relevance.** Are the contents appropriate to the students' needs, interests and abilities?
- **Validity.** Will the resource bring about the learning outcomes hoped for? What evidence is there of this?
- **Usability.** Can the resource be used by students and science educators? Is equipment simple to use and reliable? Is it flexible?
- **Variety.** Does the resource provide experiences which are not otherwise possible?

3.4 Manufactured materials

These consist of equipment and chemicals, needed specifically for teaching science and technology education, and general hardware items used in the teaching of all subjects. A list of useful manufactured resource materials for science and technology is given as Table 1.

Magnifying lens	Potassium permanganate
Measuring cylinder	Formalin
Clinical thermometer	Alcohol
Laboratory thermometer	Ammonia
Torch cell	Dilute acids
Insulated wire	Chisel
Fuse	Steel plane
Electric switch	Hammer
Ball bearing	Pliers
Pulley	Clamp
Standard weights	Calliper
Spring balance	Screw driver
Plastic tubing	Hand drill and bits
Meter rule	Assorted tiles
Funnel (plastic)	Spanner
Bar magnet	Wire cutter
Baking soda	Tin cutter
Iodine	Iron saw

Teacher educators should be familiar with materials in manufacturers' catalogues and their availability for use in schools. They should liaise closely with the Ministry or Department of Education in selecting 'good' resource materials to ensure that a common message is being given to teachers and pre-service trainees. In many countries, science kits are being supplied to schools. Teacher educators need to be aware of the contents of such kits and able to demonstrate their use to teachers and trainees.

Teacher educators need to be sensitive to the fact that resources they have in their training institution may not be available in schools. For example, teacher training colleges may have overhead projectors, whereas schools may not. While teacher educators may wish to use such resources for teaching students, they should not train the student teachers in their use unless they are available in the schools.

3.4.1 Procurement of materials

Policies for procuring manufactured resources for schools vary, and science and technology teacher educators need to liaise with schools about administrative aspects. They need to be fully aware of the existing policies and to ensure that their students understand the procedures to be followed. Such procedures might include:

- award of contract or tender by the institution or a central tender board;
- order against a budget, where schools are provided with a budget for this purpose;
- order from a resource centre – as in Nigeria.

3.4.2 Storage and maintenance

It is also important for science and technology teacher educators to teach their trainees about the proper storage and maintenance of manufactured resources. Many primary schools do not have science laboratories. The teacher educators need to look out for examples of good practice with regard to storage in schools, and discuss these with the trainees. For schools without laboratories, materials should be stored as close to the user as possible so that the chances of their being used are increased. Also, if materials are stored in glass-fronted cupboards students may see them and want to use them, thus reducing the possibility of teachers forgetting to use them.

Manufactured materials must be properly maintained to ensure their efficient operation and long-term use. Science and technology teacher educators should learn how to maintain every manufactured item used in schools and pass on this knowledge to their trainees. Poor maintenance of science equipment is a serious problem in many countries, and science and technology teacher educators have a big responsibility to correct this situation by providing proper training in maintenance to teachers.

3.4.3 Safety

Teaching about the proper and safe use of manufactured resources is another responsibility of the science and technology teacher educator. Teachers need to be shown how to use equipment so that they do not damage the equipment or injure themselves. Teacher trainers also need to ensure that their trainees are fully aware of possible dangers from chemicals they may use.

3.4.4 Equipment pools and lending systems

Many schools do not have the manufactured science equipment they need because of lack of funds. To overcome this problem, alternative means of supporting schools have been

developed. In some countries schools are grouped into ‘clusters’, which share human and material resources. Other countries have established ‘science centres’ or ‘teachers’ resource centres’ at the district or sub-district level, which store equipment and make it available to schools on request. For such a system to be effective, procedures need to be in place for the quick supply of equipment to schools or for the teachers to be able to come to the centre to collect the equipment.

3.5 Locally available materials and technologies

3.5.1 Local materials

The use of locally available materials should not be viewed as a poor alternative to using manufactured ‘bought-in’ science equipment. It makes teaching more relevant to students by relating it to their real everyday lives.

Locally available materials are those available either free or cheaply from the immediate environment. They include: wood, clay, iron filings from the blacksmith, pith, soil, grains, plants, empty bottles and bottletops, comb, wax, nails, sawdust, coal, common salt and limestone and locally produced manufactured items such as magnets, balloons, paper clips, plastic bowls and candles. Many of the items generally available in children’s homes, such as bulbs, knives, clothes pegs, razor blades, pieces of fabric, are also valuable resources.

Teacher educators should be aware of different kinds of locally available materials and their various uses in science and technology education. They should ask the trainees to collect such items and in turn advise the trainees to ask children to collect. However, enthusiastic children may collect too many things, so teachers should be advised not to ask every child to bring the same things. Asking children to volunteer to bring different items, will improve their motivation and interest in learning about things in their environment.

Teacher educators should mount exhibitions of locally available materials used in their institution for the training of science and technology teachers and encourage teacher trainees to mount similar exhibitions in their schools. Sessions should be set aside for pre-service teachers to gain practice in adapting locally available materials for teaching situations and illustrating their use in making teaching more meaningful.

3.5.2 Local technologies

Local technologies are as important a resource as locally available materials. Young learners bring with them to school, experiences of science and technology which they have observed within their homes and the wider community. Science and technology teacher educators should use these experiences during training and help their trainees to utilise similar experiences. It should be emphasised to them that local technologies have the potential to make learning more relevant and meaningful for the children by linking their real-life experiences with what they learn in school. The use of community resources for teaching science and technology also provides an excellent opportunity of introducing students to social concerns which need to be addressed. Such interaction can allow students to gain useful insight into the purposes served by technology, how technologies influence individual people's lives as well as their interaction with each other and with their environment. Moreover, parents also start taking interest in the education of their children as they feel children are learning useful things. The following panels give some examples of local technologies with relevance to science and technology education.

Production of 'Akpeshie', a local gin in Ghana

Palm wine, a sugary sap tapped from the palm tree, is allowed to undergo fermentation by being left to stand in metal drums for at least three days. During these three days, the sugar in the palm wine is converted to alcohol by the action of yeast that is present in the palm wine as a result of its being exposed to the air.

The drum containing the palm wine is connected from the top by means of small-diameter metal tubing which either passes through another drum filled with water or passes through a pond or slow moving stream to a smaller metal or glass receptacle.

When heat is applied to the drum containing the palm wine, the alcohol evaporates, passes through the tube, and is condensed by the cooling effect of the water in the pond, stream or drum and collects in the receptacle.

The 'strength' of the resulting alcohol is tested by applying a lighted matchstick to a small portion of the product. If the alcohol is 'strong' it inflames; if it is 'weak' it does not.

Repelling mosquitoes

In Swaziland a plant called 'umsutane' is used by some communities to repel mosquitoes. The insects are repelled by its scent. It is rubbed on the body or the leaves placed in strategic parts of the huts overnight.

Jelly pan 'photocopies'

This technique was extensively used when photocopy machines were not available, and is still being used in rural schools in South Africa. It works very well for drawings, graphs, sketches and printing large-letters.

You need:

- 500 ml glycerine
- 75 ml gelatine
- 450 ml water
- 80 g sugar
- 2 flat baking trays (about the size of A4 paper)
- 1 sheet of spirit carbon paper

The spirit carbon paper is not ordinary carbon paper, and must therefore be ordered by your institution from an office supplies dealer. The advantage of using it, however, is that with this method, a school can produce *hundreds* of copies with a single sheet of spirit carbon paper.

Method

1 *Presentation of jelly pan*

Dissolve gelatine in a tin of hot water. Add sugar. Boil the mixture. Add glycerine. Now boil mixture gently for another 15 minutes.

Stir continuously with a bread-knife or flat spatula. The mixture should have no bubbles and must be dissolved properly. Pour gently into the two baking trays, spreading it evenly. Smooth any little bubbles to the sides. Leave for 24 hours. Now your jelly pan is ready to be used.

2 *Making a master copy*

Arrange the paper from which you want to copy, the carbon paper and the paper on which you want to make the master copy as follows:

Top: Paper with design, drawing, graph etc. (face up)

Middle: Spirit carbon paper (can be used to make hundreds of master copies), carbon side (face down) on the white paper

Bottom: Clean white paper (will be the master copy: can be used to make imprints on a number of jelly pans)

Take a drawing or big letters which you want to copy. Arrange the plain paper, the carbon paper and your drawing on a hard surface such as a table. Make sure the face of the carbon is on the clean white paper. Now trace the boundary of the drawing or each letter so that it leaves an imprint on the white paper.

Now take the white sheet with the imprint on it and place it on to the jelly so that the imprint side of the paper faces the jelly. Press the paper gently over the jelly. You will find the imprint on the jelly. Now use this jelly pan as a master. Place paper sheets over it and press gently by hand to obtain hundreds of copies.

3 *Making copies in pupils' exercise books*

It is not necessary to tear a page out of a pupil's exercise book. Simply, put a clean page face down on to the jelly pan, smooth over the page, and the drawing is in the pupil's book! You will be able to make more than a hundred copies with one tray before it goes 'dull'. You can use the same jelly once again, just cook it for a while and repeat the process.

A method that is well worth trying out!

In many schools in South Africa mathematics is taught in an interesting way using a calendar

Choose any month and play a game of numbers and addition as follows:

M	T	W	T	F	S	S
1						
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Select any two consecutive dates and add diagonally across from each as follows:

Suppose we select 2 and 3. The number diagonally across from 2 is 10; $2 + 10 = 12$. The second number is 3 and the number diagonally across is 9; $3 + 9 = 12$. The sum is the same. Try this with any other two numbers. What is your conclusion?

1 $2 + 10 = 12$
 $9 + 3 = 12$

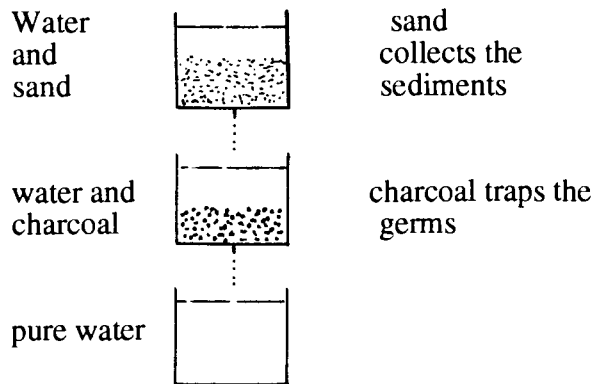
2 In the same way, add three numbers diagonally across:
 $3 + 11 + 19 = 33$
 $17 + 11 + 5 = 33$
 The sum is always the same. Try with any other three numbers diagonally across.

3 Add numbers making up a 'Z' shape:
 e.g. $5 + 6 + 7 + 13 + 19 + 20 + 21 = 91$
 You have added seven numbers. The middle number is 13. The multiplication of these two numbers (7 and 13) will give 91. Do more of these with this month or any other month.

4 Choose a rectangle of nine numbers and add them together:
 e.g. $6 + 7 + 8 + 13 + 14 + 15 + 20 + 21 + 22 = 126$
 The total is 9 times (the total of numbers added) the middle number (14).

Hint: Always check your middle term and compare it with your answer. Is there a quicker way to get to the answer?

Simple technologies are used in water filtration



Making clay pots

In Malawi, village potters have been making clay pots for many years. They have learned to choose suitable soils and oils, and to control the drying and baking processes to reduce cracking.

Despite the acquisition of technological skills, one elderly woman potter still attributed her success to a superstition:

'Since I started using my granddaughter to light the fire', she said, 'no pot has broken'.

She was referring to the baking of the pots she made. Perhaps the reason why the pots never cracked during baking was due to her mastery of the technology of pot-making.

3.5.3 Other local resources

Teacher educators also need to be aware of, and to encourage teachers to use, other local out-of-school resources. These might include:

- Visits to different construction sites to study the methods, materials and tools used. Children must be encouraged to put ‘why?’ and ‘what?’ types of questions to the people doing different jobs.
- Visits to a furniture-making factory or a carpenter’s workshop to study measurement tools, materials and techniques used for joints, techniques used to strengthen furniture, different shapes and their relationship to strength and design of the furniture.
- A local blacksmith or potter’s workshop are also useful resources for learning about tools, skills and techniques.
- In the local market place children may observe and learn about different types of foods and the popular food choices, transportation used, how different items are measured and sold, methods of preserving food, materials used to pack food, hygiene and sanitation aspects of food, etc.
- Visits to a local hospital, health centre, doctor, restaurant, garden, plant shop, railway station, etc., can be very rewarding as a means of linking real-life experiences with school science and technology.

All of these will help to integrate what the children learn in school with real life in their communities.

3.6 Improvisation of scientific equipment

Improvisation is an important aspect of science and technology education. It involves scientific processes such as problem solving, planning, decision making, designing and evaluating, which are all important for living in the modern world. Improvisation not only helps to overcome the shortage of equipment, but, equally importantly, it helps to develop teachers’ scientific process skills, technological skills and a positive attitude towards improvisation and science and technology. Many of the ‘bought-in’ manufactured items used in science and technology education could be improvised from locally available materials. Books are available which give guidance on preparing improvised materials.

Some examples of items which can be improvised include:

- balances;
- measuring cylinders from discarded feeding bottles;
- measuring cylinders or air pressure pumps from discarded syringes;
- corks from bamboo pith/raffia palm;
- gum from mixing discarded styrofoam packing material and petrol;
- concave and convex mirrors from bottoms of tins;
- indicator dye from leaf extracts;
- rulers from graduated sticks;
- acid from the juice of unripe fruit;
- formalin (preservative) from the local gin;
- funnels from the top parts of discarded plastic bottles;
- weather instruments - wind vanes and water gauges.

Science and technology teacher educators may suggest other items which could be improvised and are suitable for particular situations. They should encourage teachers to put forward their own lists of items which could be improvised, and, more importantly, demonstrate the use of improvised materials during the normal teaching situation. The teacher trainees should actually produce a few improvised items during their training.

As well as learning how to improvise, pre-service teachers should consider who might be able to help, for instance fellow teachers, local artisans or craftsmen, and the pupils themselves. Improvisation by pupils can represent a valuable learning experience if handled appropriately. Science and technology educators should advise teacher trainees on how they might go about creating a learning situation that involves pupils in improvising materials. A common approach is through problem-solving exercises or projects.

3.6.1 How to go about improvisation

An important aspect of improvisation is having the initial idea: some have been listed above. Teachers will need advice on the procedures to be followed for improvisation. A suggested procedure might be:

- examine lesson contents and specific objectives;
- identify the need for use of equipment/materials;
- write procedures for assembling improvised materials;
- assemble materials;
- try improvised materials out before final use.

Improvisation ideas should be disseminated in magazines or newsletters, such as the newsletter of a local science teachers' association.

3.6.2 Basic equipment required for improvisation

Improvising materials will sometimes require use of tools. Training institutions should have simple mechanical tools such as wooden compasses, callipers, tape measure, screw driver, punch, wood saw, metal saw, pliers, chisel, steel plane, hammer, hand drill, clamping and holding tools, spanners etc. Science and technology teacher educators should be conversant with the use of these tools and be able to guide trainees in handling them in a safe and purposeful manner. Provision should be made in pre-service and in-service training courses for teachers to handle many of these tools.

3.6.3 Attitude to improvisation

Many teacher educators and teachers do not have a positive attitude towards improvisation. They regard improvisation as an activity forced upon them by shortage of funds, and consider improvised items as inferior. It is important for them to appreciate the positive advantages of improvisation and the common disadvantages of bought-in manufactured materials:

- Many manufactured items or kits are supplied to schools without funds or a policy for replacement. They get locked into the stores or head teachers' office for fear that, if the items get destroyed or broken, either the teacher will have to pay or they may not be replaced for a long time.
- There are educational advantages in using familiar materials which can stimulate investigations and can be replaced fairly quickly and cheaply.
- Improvised materials can be available in larger quantities, possibly for handling by each student, which may not be possible with sophisticated and costly manufactured items.
- Improvisation leads to development of problem-solving skills amongst teacher educators and teachers which may be passed on to students.

3.7 Resource centres

Teachers' resource centres have been found to be very useful in some countries in promoting the development and use of locally available materials. At these centres, teachers and teacher educators meet frequently to share and develop teaching and learning materials using locally available materials. These centres can be established in such a way that 25–30 teachers work together for a whole day once in every month or two. Such a centre could be located in one school for a year or two and then perhaps rotated amongst the other participating schools. This

requires some initial funding by Ministries of Education or non-governmental organisations for buying consumable and non-consumable materials.

Such resource centres, if they are to serve the purpose, must be established within easy reach of the teachers whom they serve. Science and technology teacher educators and teachers should be able to go to the resource centres to work in groups to develop teaching and learning resources, share resources, and discuss problems and successes experienced in promoting science and technology education. These centres can also display examples of good improvised materials and other work.

Since teachers may not have time during regular school hours to improvise materials, the teachers' resource centres may provide an appropriate forum where teachers can pool their efforts and skills to generate improvised materials. Every time teachers meet at these centres there should be time earmarked for improvisation.

Science and technology teacher educators must develop skills amongst teachers to use the resources efficiently. School timetables may have to be arranged in such a way that there is no competition for materials. For example, in a school with several science teachers the timetable could be arranged in such a way that not more than one or two science classes take place at the same time.

MONOGRAPH 4

Evaluation in science and technology education

4.1 Overview

Evaluation is an integral part of the teaching–learning process. Through systematic evaluation procedures science and technology teacher educators can measure the progress of pre-service and in-service teacher trainees in attaining the objectives of teaching programmes. Evaluation also enables teacher educators to measure the effectiveness of their own teaching strategies and methods. Similarly, trainee teachers need to develop skills and competence in evaluation techniques which they can then apply in their own teaching in schools. Evaluation results can also play a part in an accountability system for ensuring that institutions, teacher educators and teachers deliver good quality science and technology education.

It is important that the objectives of a lesson or course should be clear, so that science and technology teacher educators can select appropriate learning experiences, teaching methods and information-gathering techniques in order to achieve the objectives.

4.2 Objectives

This monograph aims at helping science and technology teacher educators to:

- acquire the necessary knowledge and skills to evaluate trainees;
- acquire the skills of evaluating their own teaching;
- become aware of the problems associated with evaluation;
- become aware of the need for and methods of record keeping;
- develop the necessary understanding and skills of evaluation amongst trainee teachers.

4.3 The purpose of evaluation

Evaluation is carried out for the following purposes:

- to measure progress;
- for accreditation and certification;
- to determine whether objectives of a teaching programme have been achieved;
- to rank learners;

- to identify gaps in the knowledge and skills of learners;
- to provide information on progress to parents, teachers, teacher educators and decision makers.

The teacher educator should emphasise to the teacher trainees that the purpose of evaluation is not only to let the learner and parents know about the progress of the learner. It is also of vital importance to teachers because it informs them about the success of their own teaching. Information from evaluation can be used by teachers to plan their lessons. This should be demonstrated by the teacher educator.

4.4 Types of evaluation

The purpose of evaluation determines its type. Informal evaluation techniques may be used to collect information needed for decision-making. Evaluation may be carried out to collect a variety of information about teacher trainees, such as academic performance, performance in the classroom, ability to handle classroom material, presentation and communication skills and ability to plan and execute practical work. Similarly, teacher educators may evaluate trainees with regard to their knowledge and skills in planning and administering evaluation in school.

It is the use of the information collected which determines the nature of evaluation. If the information is used to diagnose the cause of a particular problem faced by a trainee, the evaluation is called **diagnostic**. If information gathered is used to monitor teachers' progress during pre-service or in-service programmes and to take corrective measures whenever required, evaluation is called **formative**. This type of evaluation is carried out periodically and is therefore also called **continuous** evaluation. Evaluation which is carried out at the end of a course or session is called **summative** evaluation.

4.4.1 Formative evaluation

Formative evaluation is carried out to provide the teacher, as well as the learner, with feedback that can be used in taking corrective measures at different stages in the teaching–learning process. Objectives of formative evaluation are:

- to determine the progress being made by the learners and the difficulties they may be experiencing;
- to guide the learning process;
- to decide which students need further help and the nature of activities and strategies that might help them;
- to pace the learning process and make the learner more alert to his or her performance.

Formative evaluation is conducted mainly to improve learning. This does not mean that tests used for formative evaluation cannot be graded. However, the grading is done to find strengths and weaknesses in the teaching–learning process. Formative evaluation, therefore, provides both teachers and learners with feedback on the achievement of the objectives. Teacher educators should model how this can be done in their own teaching.

4.4.2 Continuous evaluation

As the term implies, continuous evaluation is carried out periodically during the teaching-learning process. It has two main purposes:

- for formative evaluation;
- to supplement summative evaluation.

This means that the final grade a learner receives in a course is not based on a single final examination, but takes into account the results of the continuous evaluation.

Characteristics of continuous evaluation

- **Systematic.** It is systematic in that measurements to be made of the teacher’s performance at different time intervals have to be planned.
- **Comprehensive.** It is comprehensive in that it makes use of many different techniques to collect information over the range of abilities. Information about cognitive, affective and psychomotor skills may be collected through tests, projects, assignments, observations, interviews and questionnaires. This holistic evaluation provides valuable information on the teachers.
- **Guidance-oriented.** Continuous evaluation is oriented towards providing guidance in that the information obtained is used to guide the teacher trainees’ future professional development.

It is important that teacher educators demonstrate these characteristics of continuous evaluation in the evaluation of the teacher trainees and then enable the teacher trainees to use the strategies with their students during teaching practice. This will help the trainees to develop appropriate skills.

Problems associated with continuous evaluation

Teacher educators should be aware of the problems outlined below, discuss them with pre-service trainees, offer suggestions and allay fears.

- **Workload of the teacher.** There can be no denying that continuous evaluation makes demands on the teacher. Whether this work is above and beyond that which the teacher can reasonably be expected to undertake as part of teaching depends on particular situations. As was stressed above, evaluation and feedback are essential in teaching. Where continuous evaluation is used to provide feedback, it is reasonable to expect teachers to integrate this into their normal workload.

The problem with continuous evaluation arises, however, when the outcomes need to be recorded for use by other teachers and outside bodies. This usually has to be done in a standard format that involves the teachers in additional clerical work and in carrying out evaluations at stipulated periods for record keeping rather than at times most appropriate to the teaching situation.

- **Teacher–student relationship.** Some teachers are concerned that formally evaluating students will interfere with teacher–student relationships and with the role of the teacher in providing feedback and counselling. The perception is that students will be afraid to give ideas and opinions because they may be penalised during evaluation.

Teacher educators must realise that evaluation and feedback are one and the same and that evaluation, of any form, needs to be an integral part of teaching. When students understand this and are able to establish and accept the need for evaluation and feedback, the teacher–student relationship can be enhanced. It appears that the fear of teacher trainees is associated with an inability to link evaluation with teaching.

4.4.3 Summative evaluation

Evaluation which is carried out at the end of a course with the sole purpose of grading, promotion or selection is termed summative evaluation. Results of summative evaluation are also used for accountability purposes of individual teacher educators or teachers or of their institutions. Summative evaluation also informs policy makers about the standards of education and the efficacy of the curriculum.

Summative evaluation is normally carried out using paper and pencil tests and/or practical tests administered towards the end of a term or academic year. Such tests may be conducted by the institution itself or by an external examining agency.

In some countries, teacher trainees' success or failure at the end of a teacher education programme is mainly determined by an external examination body. It has been advocated that teacher educators should have some input in determining the final grades of their teacher trainees.

For a valid evaluation of the student teacher, the results of continuous evaluation should be used to supplement summative evaluation.

4.5 Methodology of evaluation

Harlen (1983) has suggested that evaluation begins by asking a few questions. She suggests the following sequence of questions:

- What is the purpose of evaluation?
- What information is required to serve the purpose?
- What methods are appropriate to gathering this information?
- What form of record is suitable for accumulating the information?
- What interpretation and use are to be made of the information?
- Does this use serve the initial purpose?

The first four questions must be asked before the evaluation takes place and the last two after the information has been collected through informal means such as observation or formal means such as tests. Thus the purpose of evaluation and the information required for making judgements determine the tools and techniques to be used to collect the information.

Teacher educators should ask themselves these questions when planning evaluation of trainees. After the evaluation exercise has been completed the teacher educators should discuss the basis of decisions on each question with the trainees. This will help the trainees to see evaluation in action and identify appropriate method(s) for collecting a particular kind of information, and the most suitable method of recording it. The trainees may then be given appropriate assignments to practise these skills. They may be asked to decide the kind of information to be collected, the tools and techniques to be used to collect the information and the form of record to be kept. A common mistake which occurs is to set a task or question designed to evaluate a particular objective or criterion which does not provide opportunity for the learner to demonstrate the achievement of that objective. This must be avoided.

In order to give practice in the interpretation and use of information collected, trainees may either be given some hypothetical information to interpret or asked to collect information themselves and interpret and use it. It is important for teacher educators and the trainees to know that the purpose of evaluation and the type of information collected could inform vital decisions. These decisions may be regarding the achievement of each learner or the class as a whole, difficulties being faced by individual learners and the class, the efficacy of the teaching–learning strategy utilised, and remedial activities that may be necessary.

Nature of information required for evaluation

The nature of information to be collected for different purposes depends upon the objectives being evaluated. In most countries the objectives relate to the cognitive, psychomotor (including processes) and affective domains, but the emphasis placed on each varies, as the following examples illustrate. In some countries there is heavy emphasis on content while in others the emphasis is on the development of psychomotor skills. The development of scientific attitude, interest and values is emphasised by all to varying degrees.

In **Namibia**, the syllabus gives the aims of the science course as:

- to acquire sufficient understanding and knowledge to become citizens of a confident world;
- to take or develop an informed interest in matters of scientific importance;
- to recognise the usefulness and limitations of scientific processes and appreciate their applicability in other disciplines and in everyday life;

In the **Kenya** Syllabus for Primary Schools Science, the objectives for standards 1–3 emphasise the development of attitudes, skills and acquiring information about the immediate surroundings through first-hand observation.

In **Nigeria** the objectives of science teaching are the acquisition of basic scientific skills: observing, manipulating, classifying, communicating, inferring, hypothesising, interpreting data and formulating models.

In **Uganda** the objectives of science teaching are to develop in children skills of observation, experimentation and evaluation.

Thus, the objectives of science and technology education about which information will have to be collected are in the areas of:

- knowledge and understanding of scientific facts, principles, methods and materials;
- process skills such as observation, classification, communicating, inferring, hypothesising, experimenting, designing and problem solving;
- attitudes, interests, curiosity, critical thinking, perseverance, openness.

4.6 Information-gathering techniques

A variety of techniques can be employed to collect information about learners' progress. These techniques may be classified as:

Formal

- written tests;
- practical tasks carried out by individuals or groups;
- questionnaires;
- scheduled interviews;
- rating scales;
- check lists.

Informal

- observation during normal activities;
- written records of work produced including drawings;
- listening to oral explanations.

4.6.1 Evaluation of problem solving

To solve a given problem, a learner has to use certain ideas and skills. From the point of view of evaluation, it is vital that these are carefully identified and documented, so that the extent to which they have been used successfully can be evaluated. For the purposes of grading and assessing progress, a series of statements in terms of what learners will or will not be able to do at each stage should be needed. Each stage can be assigned a mark. The panel shows how this approach is being followed by the INSTANT project in Namibia.

Possible investigative skills to be assessed and developmental stages

SKILL 1: Using and organising techniques, apparatus and materials

Stage 1: Can follow written, oral or diagrammatic instruction to carry out one operation; needs help to do more; uses familiar apparatus adequately, but needs showing how to use unfamiliar apparatus; rather thoughtless over safety points.

Stage 2: Can follow written, oral or diagrammatic instruction to carry out an operation involving a series of steps and uses familiar apparatus adequately and safety; needs demonstration of how to use unfamiliar apparatus.

Stage 3: Can follow written, oral or diagrammatic instruction to carry out an operation involving a series of steps and is able to modify the instructions to improve the operation of the equipment; uses familiar apparatus adequately and safely; can make a fair attempt at using unfamiliar apparatus.

SKILL 2: Observing, measuring and recording

Stage 1: Can follow detailed instructions to make observations; can make simple measurements using a simple measuring device; records results in an appropriate way when shown how to do so.

Stage 2: Makes measurements, given a brief outline of how to do it; can use some more complex measuring devices such as those having a scale where 1 division is equal to 0.1 of a unit or 2 units; reads most devices but may not do so with complete accuracy; records results in an appropriate way given an outline format.

Stage 3: Makes relevant observations that are as accurate as possible; can read any scale correctly; records results correctly without being given a format.

SKILL 3: Handling experimental observations and data

Stage 1: Can process results adequately given detailed instructions on how to do it; can draw one obvious conclusion from the results.

Stage 2: Can process results adequately given outline instructions on how to do it; can recognise results that might have experimental errors; can draw conclusions from the data.

Stage 3: Can process results adequately without help, recognises experimental errors and knows how to deal with them; can identify possible reasons for the error; can draw conclusions; and also makes general deductions from data.

Skill 4: Planning and investigating

Stage 1: Can suggest a simple experiment to investigate a practical problem, although this may not work; can attempt modifying the experiment if it does not work.

Stage 2: Can list a series of steps to carry out an investigation; can modify the steps that do not work well; can recognise the need to control variables though may not be very clear about how to do it systematically.

Stage 3: Can list a series of logical steps to carry out an investigation that is likely to work in practice; modifies the steps that do not work well; recognises the need to control variables in a systematic way.

4.6.2 Evaluation through observation during normal activities

Observation (as a technique to collect information) provides qualitative information about the objectives being evaluated. Through observation, skills, attitudes and acquisition of concepts can be evaluated over an extended period of time. Since the learners are being evaluated through observation of their normal activities, they are not under stress; also, there is no loss of

teaching–learning time. All the learners need not be evaluated at the same time through one activity. To aid observation, actual classroom activities could be video-recorded. These recordings could also be used by trainees to develop and practise observation skills.

Observation is a very powerful information-gathering technique since it can be used to collect information about a wide range of behaviours spread over several objectives. However, the teacher educators and the teachers need to recognise that observation goes beyond simply looking at what students are doing. For the technique to be used successfully, the activities to be observed and the particular stages within them, must be clearly identified. The emphasis is not on observing whether or not the learner is doing the right things but on what the learner can or cannot do.

In addition, criteria have to be established, against which observations can be measured and recorded. The criteria are generally derived from the learning objectives and the stage of development of the trainee. This aids proper interpretation of the observations and in establishing the learner’s progress, information which is very useful for the teacher educators and teachers in planning future activities for the learners.

One disadvantage of collecting evaluation information through observation is the element of subjectivity. The observer has to be skilled in the technique: an unskilled observer may miss certain important factors that should be noted.

4.6.3 Using written tests for gathering information

Written tests may contain a variety of questions such as:

- short-answer;
- essay-type;
- multiple-choice;
- fill in the blanks.

Written tests are used mainly for collecting information about students’ cognitive abilities and some drawing skills. They cannot be used for testing a wide range of psychomotor skills. They can, however, be used for both formative and summative evaluation. Most written tests include essay-type and multiple-choice questions, and some characteristics of these are listed below.

Essay-type questions

These questions require more extended written answers and the ability to integrate and express ideas involving:

- description, explanation and prediction of processes and structures;
- description of instruments, apparatus, etc.;

- factual knowledge;
- presentation of theoretical knowledge;
- interpretation of experimental and numerical data;
- discussion of results of experiments and solutions of problems.

Advantages

- They reduce guesswork in answers.
- They reduce the possibility of cheating.
- They provide freedom of response.

Disadvantages

- In marking essays, the teacher tends to carry impressions from one paper to another.
- Essays cannot be used effectively with learners with low levels of language development.

Evaluation through essays at primary school level should be limited to short paragraphs only.

Multiple-choice type questions

Multiple-choice questions can be useful in covering a range of curricular objectives. A multiple-choice question usually consists of a question or statement, called the 'stem', followed by four or five choices of answers or 'options'. The stem may also be a partial statement that is completed by one of the choices. Only one of the options is the correct answer to the question or ending to the statement. The other options are called 'distracters'.

Other forms of multiple-choice questions include:

- **True/false questions.** These are not particularly useful since there is a 50% chance of guessing the right answer.
- **Fill-in-the-blank questions.** Here possible responses are supplied to the learner, only one of which is correct.
- **Matching questions.** These are presented in the form of two lists of statements. For each statement in one list there is one correct statement in the other list and the learners have to match them. The primary cognitive skill tested by matching exercises is recall.

Teacher education programmes should include practice in the construction and review of different types of questions and written tests. The review should include analysis of each item of the test.

4.6.4 Evaluation of individuals in group work

Most evaluation in science and technology education is carried out by teacher educators, but student teachers can be good evaluators of each other especially when they work as a group on an activity. An example of how this works is drawn from South Africa.

An innovative teacher in a school, at St Stithians, South Africa, came up with an interesting approach to evaluating group work

An overall point (percentage) is awarded for the activity or assignment of the group as a whole. The members of the group then decide how the marks should be distributed amongst themselves, according to the contribution each made to the work. The total marks for individuals must, in the end, equal the mark the teacher gave to the group. If they feel they all contributed equally, they can each earn the same percentage. According to the teacher, this strategy works very well. Within a group, each individual knows very well who did the work or who was just sitting around!

4.7 Record keeping

There are many different ways to keep records of learners' achievements and progress. The nature of the record depends to a large extent upon the technique used to collect information. For example, the record of an observation tends to be descriptive, giving information on the absence or presence of the trait being observed. Similarly, the record of a written test tends to be numerical. The type of record to be maintained also depends upon the purpose or use of the record. In general, a numerical record is not useful if one wants to know what learners can or cannot do. But if the purpose is grading the learners then a numerical record is more useful than a descriptive record.

During formative evaluation, most of the information gathered is interpreted and used immediately for taking corrective measures in the learning activities of individuals and for planning future activities. A record of the stages of development reached by the learner can be very useful in deciding long-term activities.

A common practice is to prepare a list of activities and tick them off as individuals complete them. This kind of record is not very helpful since it does not tell the reader what the learner can or cannot do. To improve the usefulness of such a list, a column can be added where the skills observed/achieved could be written. Alternatively, a list of possible skills to be assessed could be drawn up, and for each learner the particular skills observed/achieved ticked off.

Activity no.	Skill 1	Skill 2	Skill 3	Skill 4	etc.
Name 1					
Name 2 etc.					

4.8 Profiles

A profile is a method of building up a picture of attainment that allows separate grades, scores, marks and other measures to be recorded for each student. The picture can be broadened by including factors such as attitudes, health data, punctuality, absenteeism and self-esteem. These additional attributes can be judged on, say, a 3- or 5-point scale.

Profiles can be of two types:

- An extension of the conventional evaluation data, in the sense that student performance is reported on a larger number of dimensions.
- Information presented as a record of the student's abilities, skills and attitudes, which are explicitly stated and which describe the student's characteristics and attributes on a criterion-referenced basis.

In the first type of profile, the data obtained from examinations is put forward as a kind of report. The data are presented in greater detail in the sense that greater numbers of subdivisions are included. But the data themselves are still either the percentage scores, or the percentages related to a 3- or 5-point scale, which may be numerical or labelled, for example, above average, average, below average. When the middle grade is labelled as average (average for the student population), the profile is said to be based on norm-referenced evaluation.

4.8.1 Developing criterion-related profiles

If adequate information is given about the learners, the profile system mentioned above can be meaningful. But in the absence of such data (which is often the case), more meaning is attached to the profile by including the specific criteria against which measurements are taken. There is

however a tendency for the profiles to be based on criteria and be related to criterion-referenced evaluation.

In a criterion-referenced profile, the numbers represent a 5-point range, with 5 being a high proficiency and 1 a low proficiency rating. The numbers could be easily substituted by grades or use could be made of other systems. For example the ability to use a scientific instrument could be graded as:

- 5 = can use a scientific instrument accurately and safely;
- 4 = can use a scientific instrument, with guidance, and is aware of safety aspects;
- 3 = can use a scientific instrument, with guidance, but is not aware of safety aspects;
- 2 = cannot use a scientific instrument, even after guidance, but is aware of need for safe practice;
- 1 = cannot use a scientific instrument, even after guidance, and does not consider safety aspects.

4.8.2 Extending the profile

Profiles can extend beyond characteristics that relate to cognitive ability or practical skills. The example below shows part of a profile covering aspects of attitude. Again, a criterion-referenced format is being followed.

Relationship with fellow students	
4	A leader/dominant personality
3	Accepted member of student groups
2	Likes to join with other students, a follower
1	Independent, quite isolated; tends to be on his/her own
Ability to work with others	
4	Works well as the leader of a team
3	Works well as a member of a team
2	Prefers to work on his/her own
1	Does not fit in well as a member of a team
Punctuality in the last year of school	
3	Excellent
2	Some lateness
1	Poor
Discipline	
4	Self-discipline – able to relate to a normal adult/child, teacher/student situation
3	Accepts a specified pattern of behaviour and rules
2	Accepts an imposed pattern of behaviour and rules where there is a degree of supervision
1	Does not always accept a pattern of behaviour required by the student group

4.8.3 Problems with profiling

There are three main issues associated with the profiles as a method of record keeping:

- the time it takes to develop and maintain the profile;
- the type of profile to be designed and the qualities to be described in them;
- the technical aspects of the educational measurement on which the profile is to be based, including validity and reliability.

The type of profile developed depends on the needs of the end-user.

Profiles are usually developed to show what a student can achieve. It is a record of achievement and attitudes. The technical aspects of the profile are to do with the development of levels that show gradations in academic achievement or attitudinal development. The acceptability or validity of the profile depends on how meaningful the statements being made are to the end-user.

MONOGRAPH 5

Co-ordinating science and technology education

5.1 Overview

The current trend towards the provision of a broader general education in schools implies the need for a more cross-curricular approach to education at all levels. In science and technology education, calls for curricula which will produce socially responsible, technologically and scientifically literate citizens, also point in the direction of an interdisciplinary approach.

Such an approach can best be achieved in the context of co-ordination between all levels of education, and between educational institutions and all those external bodies which have an impact on them.

The usual structure of university degree programmes makes it unlikely that there would be many teacher educators with competent in both science and technology. However, the contents of these disciplines lend themselves ideally to cross-curricular links. Additionally, many organisations external to, but which impact on teacher education, are involved in activities that are relevant to both these subjects.

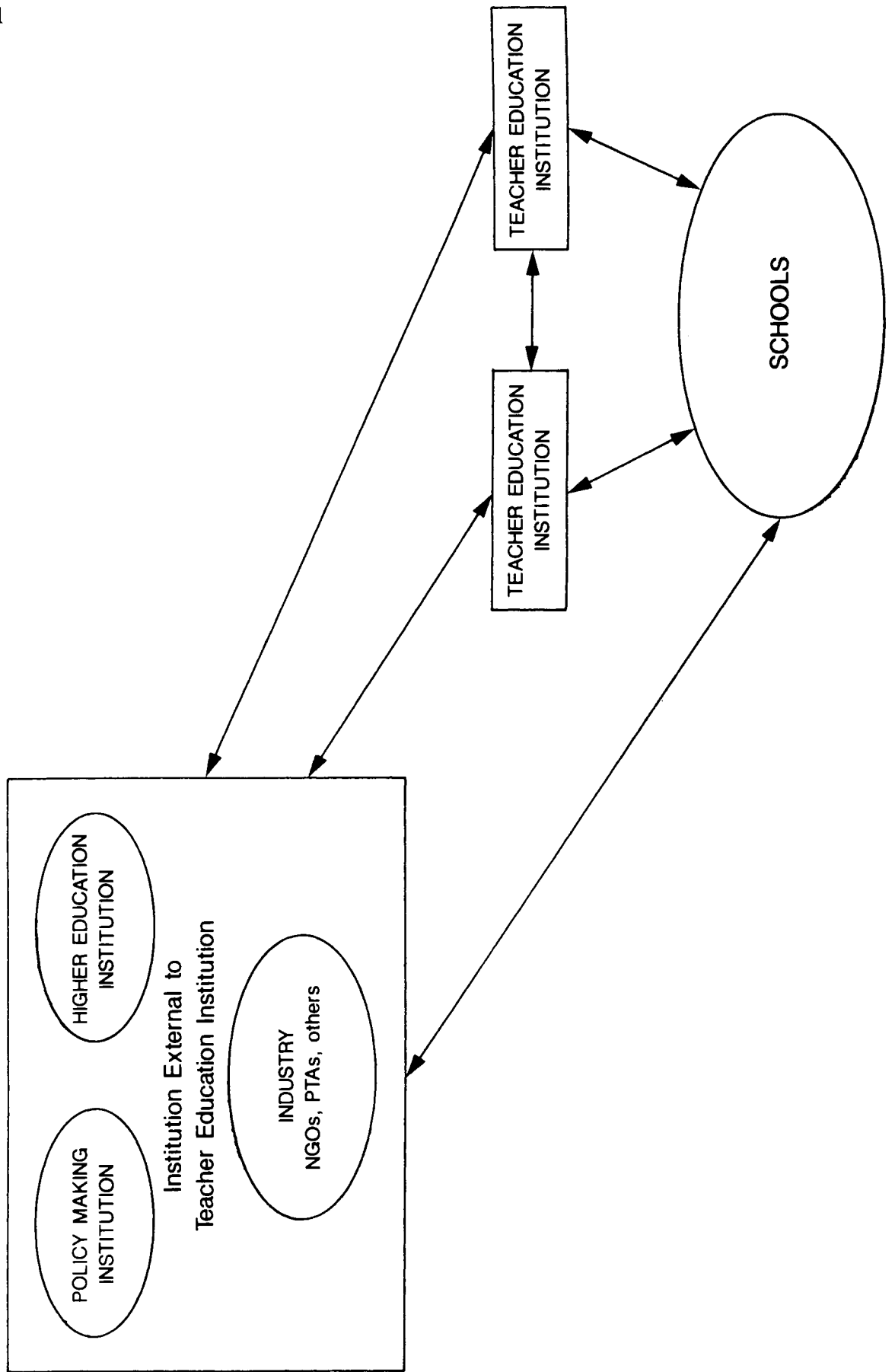
Co-ordination is considered here at three levels:

- Between institutions of teacher education and those agencies and organisations which influence them, either directly through the making of policy, or through the professional development of teacher educators; or less directly through their influence on the social, economic or cultural climate in which teacher education takes place.
- Within and between teacher education institutions themselves.
- Within and between schools.

This view of co-ordination envisages a set of mutually interactive relationships occurring within and across all three levels (see Figure 1).

Figure 1

LEVELS OF CO-ORDINATION IN
SCIENCE AND TECHNOLOGY EDUCATION



5.2 Objectives

The objectives of this monograph are:

- to inform science and technology teacher educators about those organisations, their policies and practices which must be considered in the education of teachers;
- to enable science and technology teacher educators to identify those agencies which can influence science and technology in their own contexts;
- to provide guidance on how science and technology teacher educators can influence co-ordination at all levels.

5.3 Co-ordination with institutions and organisations external to the teacher education institutions

Some of these are concerned with policy, others with professional training and/or academic growth, and still others with providing support for teacher education.

5.3.1 Organisations and institutions concerned with policy

Ministries of Education

The Ministry of Education decides on the national priorities and policies for education. Science and technology teacher educators should be aware of relevant policies. These may be contained in a general policy document of the Ministry of Education with a section on science and technology or there may be a separate policy document. This is likely to include policy statements and guidance on:

- the type of science and technology to be taught in schools;
- the general methodology to be followed in delivering science and technology to children;
- the assessment procedures to be followed;
- any in-service training which will be provided to teachers and others.

The Ministry of Education usually manages the appointment and placement of teachers, provides material resources to schools, supervises schools, and advises on textbooks and other learning materials. Science and technology teacher educators should be aware of their Ministry's policies and placement practices, of the kind of physical resources provided to schools for science and technology, and the policy with regard to their maintenance and replenishment. Teacher educators should have an input into the formulation of these policies

and practices. Ministries of Education also decide on staff development policies, another area with which the teacher educator must be familiar.

Practices with regard to school supervision and inspection, such as its frequency, procedures and nature, are also determined by the Ministry of Education. Teacher educators can help to allay teachers' understandable apprehension about the content and method of inspection by making student teachers aware of inspection procedures.

Curriculum development units

The importance of a well developed and managed curriculum is well recognised. The responsibility for this task resides with a curriculum development unit, which usually comes under the aegis of the Ministry of Education. Tuition given by the science and technology teacher educator is more likely to be relevant and contextual if curriculum development is a collaborative effort involving teacher educators.

Science and technology education can benefit from a cross-curricular approach. The curriculum guidelines provided by the development unit should encourage such an approach and facilitate its implementation.

5.3.2 Organisations and institutions concerned with professional training and/or academic growth

Higher institutions

For their own professional and academic growth, science and technology teacher educators should co-ordinate with higher education institutions concerned with science and technology content and pedagogy. They should attempt to attend meetings, workshops, seminars and short courses organised by these institutions in areas which are of interest to them.

In order to facilitate a cross-curricular approach in science and technology, teacher educators should press these institutions of higher learning to provide:

- Short courses which allow teacher educators to upgrade their knowledge as required. For example, technologically oriented courses, ideally enhanced by using resource personnel from industry.
- Broad-based degree programmes to allow students the opportunity to pursue integrated degrees.

Within teacher education institutions, opportunities for participation in these seminars, workshops and courses, need to be planned for to enable all members of the science and technology staff to participate.

INSET agencies

In-Service Education and Training (INSET) is usually conducted by the Ministries of Education, whereas pre-service teacher training is organised in colleges and universities. Where both are avenues to gaining the same teacher qualifications, it is important that the philosophy underlying them is similar. Both sets of agencies should be in constant communication, so that those completing their courses will have equal opportunities in the workplace.

5.3.3 Support organisations and institutions

Examination and assessment agencies

If teachers have been taught to follow a teaching approach which emphasises processes and problem-solving in science and technology, but the examinations test only recall of knowledge, teachers will abandon or modify their approach and adopt a didactic approach more suitable for memorising the knowledge needed for passing the examination.

At the college level, within and across colleges, teacher educators in all subject areas should co-ordinate their efforts to ensure that examinations reflect the teaching approaches used.

At the school level, the problem calls for co-ordination between the curriculum unit and the examining agency. If there is no co-ordination, teachers will tend to follow the approach most suited to getting pupils through the examination. Differences between examination and curriculum policies and practices clearly have implications for the education of teachers.

Problems may also be caused if the examination system does not take account of pupils' performance in continuous assessment in the award of the final grade. It will need to be made clear to student teachers, that continuous assessment in the classroom provides valuable feedback for the improvement of learning and teaching, even if it is not required for formal examination.

Professional organisations

Science and technology teacher educators will find it helpful to be involved with relevant professional organisations, to know of their current activities and understand the issues that concern them. Such professional contacts will help the science and technology teacher educators to make pre-service teachers aware of current issues and work with them so that they

themselves can contribute to current debate and appropriate activities when they become teachers.

Local industry

To ensure that science and technology is relevant and realistic, particularly in its technology aspects, teacher educators will want to draw examples from local, traditional and modern industry. Local industry is an excellent resource since it provides real contexts and genuine problems. Teacher educators should co-ordinate with local industry so that they may draw on their human and material resources. This should be a two-way flow of information and skills. If possible, science and technology teacher educators should visit various industrial plants for short periods, so as to familiarise themselves with the demands of these industries. Similarly, persons from industry might visit teacher education institutions for lectures, discussions or demonstrations or firms might provide teaching materials or equipment.

Such co-ordination will not only help science and technology teacher educators develop realistic activities, but help industry to understand how science and technology are taught in school, and thus develop confidence in their local teaching institutions. Science and technology educators will also gain an understanding of the requirements of industry, and the kind of curriculum which will meet these requirements.

Schools

Co-ordination with schools is needed for the purpose of:

- practice teaching;
- action research;
- providing professional support;
- understanding the working environment;
- acquiring first-hand experience of working with children.

To keep up to date with current practice in schools, it is important for science and technology teacher educators to devote regular periods of time to working in the primary school, alongside science and technology teachers. Such time, is invaluable in helping teacher educators to keep their own teaching realistic.

Teacher educators might also promote science and technology in the primary school by encouraging principals to adopt flexible time tabling arrangements, for example, block time tables, which allow class teachers flexibility across subject areas.

5.4 Co-ordination within and between teacher education institutions

Co-ordination and collaboration between the colleges of education will provide an avenue through which teacher educators can foster their own professional growth, promote some uniformity in the quality of experiences provided for teacher trainees, and develop cross-curricular links and interdisciplinary approaches. These may be achieved through:

- Developing professional organisations for science and technology educators. These may relate to the two disciplines separately, or in any combinations as the specific circumstances of different countries dictate.
- Promoting regional co-ordination between such national professional organisations.
- Mounting workshops, seminars or conferences for sharing ideas on teaching approaches and resource materials, and for engaging in discussion on current issues and trends in science and technology education.
- Preparing position papers representing the consensus views of teacher educators as a means of influencing policies and decision-making with respect to teacher education.
- Making proposals for new directions in teacher education in response to prevailing social, economic or cultural influences
- Fostering collaborative approaches to teaching, such as team teaching and team planning
- Developing theme and project approaches to teacher education. As well as improving the delivery of the science and technology teacher education curriculum, such approaches will benefit teacher trainees by providing them with models for cross-curricular approaches in their own classrooms.
- Exchanging human and material resources within and between colleges and both nationally and regionally.

5.5 Co-ordination of in-school activities

Teaching science and technology in schools involves the organisation of a number of activities. These may be broadly classified as:

- those directed towards the professional growth of teachers;
- activities directed towards effective teaching and learning;
- co-curricular activities leading to promotion of science and technology amongst students and the community.

5.5.1 The science and technology co-ordinator

For effective implementation of science and technology education programmes, a staff member needs to be designated as an science and technology co-ordinator. It could be the head-teacher, or an enthusiastic class teacher in the school with an interest in developing science and technology. Their teaching load may have to be marginally reduced to make room for the demands of co-ordination.

5.5.2 Co-ordination of activities for the professional growth of teachers

Activities which promote the professional growth of teachers normally take the form of participation by teachers in meetings, seminars, workshops and INSET courses. Such activities are usually organised by the Ministry of Education, colleges of education and teacher associations. Activities are also organised in schools by those teachers who have had the benefit of attending INSET programmes.

Ministries of Education organise INSET courses for a variety of reasons:

- to introduce a new curriculum;
- to introduce a new teaching methodology;
- for upgrading content;
- for certification of untrained teachers;
- for introducing a new assessment or supervision system.

Depending on the nature of the INSET course, the Ministry of Education may specify the number of teachers from each school who will attend the course. If the course is for a limited number of teachers from a school, the co-ordinator will be responsible for selecting those teachers who would benefit most from a course. If it is a course for content upgrading, for example, it would be inappropriate for a new science graduate to attend. On the other hand, a course leading to teacher certification would be most suitable for an uncertified teacher. To

facilitate selection, the co-ordinator will need to maintain the following record for each teacher in the schools:

- educational qualification;
- teaching experience and results produced;
- participation in science and technology education workshops, seminars and so on, with dates;
- strengths and weaknesses.

The science and technology education co-ordinator must ensure that the teacher who attends an external INSET course organises a meeting of all the school's science and technology teachers and briefs them on the course attended. This feedback will serve three purposes:

- it will help the teacher to consolidate what he or she learned on the course;
- the teacher will have to be a more attentive when on the course, knowing that he or she will have to present it themselves when they return to school;
- other teachers will benefit from the course.

Thus one course can benefit more than one teacher in a school. In addition, the course providers can benefit from the teacher's report on his or her feedback to school, so that the course itself may be improved.

The focus of the teacher's feedback briefing to school should be:

- implications for teaching and learning within the school;
- changes which could be made within the school in relation to these implications, which would make the science and technology and teaching more effective.

5.5.3 School-based INSET for professional growth and effective teaching and learning

In the busy school schedule, teachers rarely have time to sit together and share experiences. In a large school, teachers may be facing some common problems which could be resolved through sharing experiences and discussion. Similarly, some teachers may have success stories and unique classroom experiences which may benefit other teachers. It is therefore always useful if the co-ordinator can arrange for the teachers in a school to meet, possibly after school or at a weekend, for, say, half a day each month. The object of this meeting would be pre-determined through mutual consent, and known to all teachers concerned beforehand, so that everybody comes prepared. It is important for the co-ordinator to plan the meeting, draw up a timetable, and assign responsibilities. Teachers should be encouraged to volunteer to take up responsibilities rather than be coerced.

School-based INSET programmes, though generally short, can be useful in:

- preparing teaching–learning materials by sharing ideas;
- improving materials;
- resolving conflicts arising out of the use of resources;
- disseminating action research findings and generating ideas for action research;
- developing collaborative work amongst teachers.

A major advantage of a school-based INSET programme is that the innovations can be sustainable. Since new ideas are being generated and tried out amongst colleagues, the chances of successful innovation are greater. A new idea coming from a colleague is much more likely to be accepted than one imposed from an outside source. Thus, school-based INSET programmes are not only useful for the professional growth of teachers, but contribute to improved teaching and learning. Alternatives to school-based programmes may be needed for smaller schools and for those where teachers are not willing to try new ideas.

5.5.4 Co-ordination of resources

This is another important role of the co-ordinator. In primary schools, the resources supplied by the Ministry of Education are generally limited. Most of the materials required for science and technology education will be drawn from the immediate environment. The co-ordinator will need to ensure that while the materials are safely stored, they are also easily accessible to the users. This means discussing this with the relevant teachers and identifying a place suitable for all of them. Over a period of time students and teachers of senior classes may develop teaching and learning materials which could be useful in junior classes. Such products should be identified, displayed and stored, and teachers encouraged to use them.

5.5.5 Co-ordination of extra-curricular activities

The science and technology co-ordinator can encourage activities such as those listed below, aimed at developing the interests of children in science and technology. These will also need proper co-ordination.

- **Debates and quizzes.** Science, technology and mathematics-related issues can be debated by pupils. Quizzes taking the form of question and answer can be devised. As part of an INSET programme, teachers could build up a bank of topics for debate and questions for quizzes. Careful selection of topics for debate and quiz questions within the school setting can arouse interest and encourage children to explore the relevance of science and technology to the out-of-school environment. Topics which encourage girls to participate in science and technology should be given preference. Inter-school competitions allow teachers to exchange

ideas about more effective ways they may have developed for teaching science and technology concepts and skills. Students could also gain from sharing ideas with their peers in other schools.

- **Fairs, exhibitions and museums.** Periodic school fairs and exhibitions of science and technology materials made by pupils and teachers can be arranged. Exhibits can form the basis for a more permanent school museum that can become a resource for future generations of students. Labels showing the names of students and dates should be attached to exhibits to boost the morale of their creators. The items exhibited could be projects carried out by the pupils. Exhibits that show links between science and technology in schools and community activities can be particularly encouraged. Schools should also be encouraged to participate in exhibitions organised by other schools and agencies.

- **Science and technology clubs.** Science and technology co-ordinators should discuss the formation of a science and technology club within a school and how this might function. Ideas from the teachers and students can be shared and a report compiled with recommendations for teachers to implement. Science and technology clubs can be a useful way of encouraging the exchange of ideas and promoting excellence in science and technology. In such clubs students can pursue science-related hobbies and extend the concepts that they have learned in class. It could be a junior engineers' club, a technicians' club, flying club, photographic club, maths club or general scientific club. The clubs could be named after well-known scientists or engineers, or a local traditional industrialist whose skills are widely respected. Every effort should be made to name some clubs after women who have achieved prominent positions.

- **Weekend rallies.** Teachers can encourage informal learning by organising weekend rallies. In a relaxed atmosphere, pupils can exchange ideas and work on science and technology activities. These rallies can be used to attract and encourage girls to study science and technology and to pursue related careers. They could take the form of science and technology 'clinics' where girls could meet and talk to role models and mentors. Girls could be encouraged to visit science and technology based institutions and industries and engage in hands-on activities. These rallies serve to stimulate pupils' interest and popularise science and technology in the community.

- **Science and technology news and bulletins.** A bulletin board on which children's and teachers' work can be displayed, along with relevant news items, can be a very effective means of stimulating interest in science and technology. The content should reflect children's activities and teachers' accomplishments. Children can be asked to write short descriptions of their science and technology class activities for display on the board. They should also be

encouraged to read the news or bulletins during school assembly. Any science and technology-related news from the newspapers should be read and explained for the benefit of everybody.

- **Science and technology awards and souvenirs.** Awards and souvenirs for outstanding pupil performance can also stimulate interest in science and technology. To promote science and technology amongst girls there could be awards exclusively for girls. Award winners can be identified and presentations made to them by pupils or by well-known figures from the community. Similarly, awards can be given to teachers for effective teaching and innovations in science and technology education. The community must be encouraged to promote such awards: involving the community in the choice of award winners will develop an active interest in science and technology in the school amongst the community.

MONOGRAPH 6

Participating in science and technology education research

6.1 Overview

Educational research is the only sound basis for effecting improvements to the educational system. Its practitioners – teacher educators and teachers – are the most important resource in science and technology education. With them lies our best hope of finding solutions to the problems of science and technology education at the primary level in our schools. They are the agents of change. They know the problems, the subject matter and the demands of the relevant disciplines. They know their pupils' changing needs, interests and aspirations. They are aware of existing conditions in their classrooms and local environments. As part of the local community, they are conscious of what parents expect of schools. No one is better placed to recognise the first indications of success or failure in implementing curricula, and to effect the necessary improvements and changes in the classroom.

It is therefore vital that teacher educators participate in research and are able to guide and steer teachers towards developing a positive attitude to research in their classrooms.

Science and technology education research belongs to the classroom. Improvements to science and technology education at the primary level can be realised through teacher educators' and teachers' participation in research, both as researchers and as users of research findings.

6.2 Objectives

This monograph aims to:

- stimulate the interest of teacher educators in science and technology education research by outlining the advantages of participation in research;
- encourage teacher educators to develop their research skills;
- assist teacher educators in developing the action research skills of teachers.

6.3 What is science and technology education research?

Science and technology education research can be broadly characterised as activities that:

- through problem identification, information-gathering and analysis of data, lead to a better understanding of problems in science and technology education;
- produce findings which lead to improved classroom practices, programme planning and implementation, and more informed policy decisions at the school or college level.

An example of research leading to improved practice

Matthew is a teacher in a well-endowed urban primary school situated near a teacher training institution in Ghana. He became anxious about his pupils' difficulties in understanding the particulate nature of matter. After consulting Ian, a science teacher educator at the teacher training institution, they decided that Ian should observe Matthew's classroom as he taught the topic 'particles in nature' to his class the following year.

Ian's study of Matthew's class involved observation, audio-taping, examination of the textbook, and interviews with Matthew and some of the pupils in the class.

Three issues became clear from the information Ian collected:

- Matthew's teaching in class was text-bound;
- he worked on the assumption that the particulate ideas were simple enough for pupils to understand;
- pupils were unable to apply the particulate ideas. They thought that particles expand, melt, reduce in size, break up on application of heat, and that in a solution of water sugar particles remain particulate while the water is continuous.

Matthew, with Ian's help, then developed five lesson plans on the particulate nature of matter, which utilised the constructivist approach. The development of these plans took Matthew out of his classroom once a week for six weeks. Part of this time was used in trying out the activities with Ian's help. Matthew taught the new lessons while Ian observed and recorded. After each lesson, which required pupils to carry out activities that challenged their prior ideas about particles, Ian interviewed Matthew on some of his actions. Pupils were also interviewed, using questions prepared jointly by Ian and Matthew.

The findings indicated a marked change in the initial ideas of almost all the students in the class. Matthew commented on the confidence he had gained in using the constructivist approach and was determined to use it in teaching other topics.

Research can be carried out using interview, observation and audio-video recording to collect in-depth information on a problem such as teachers' and students' use of curricular materials, and teaching particular science and technology topics. When narrative information is collected and used to give a detailed account of the problem under investigation, the approach to research

is described as **qualitative**. In this approach to research, the emphasis is not on drawing generalisations but on describing a situation in detail.

In the **quantitative** approach to research, a problem is analysed by collecting numerical data through the use of questionnaires, tests, attitude scales and observations. In quantitative research the emphasis generally is on drawing generalisations. Qualitative research can support quantitative research and vice versa.

EXAMPLE 1: Quantitative research

Research done by Parker and Rochford (School of Education, University of Cape Town) was directed towards young scientists' perceptions of the nature and method of science.

The 1993 modified 'Aikenhead scales' were employed to measure the perceptions of the nature and method of science held by:

- (a) 82 keen young scientists and mathematicians who had entered the annual Science Talent Quest (EXPO) competition at the University of Cape Town;
- (b) 391 of their non-specialist mainstream classroom counterparts in the more general senior science years of five representative high schools in Cape Town.

A statistical analysis of the responses of the two samples to 26 items on the three scales, disclosed significant differences with respect to the relative importance attached by the two groups to:

- finding cures for diseases and helping the environment;
- exploration of the unknown and discovery of something new;
- finding and solving puzzles;
- formulating theories to explain things;
- careful recording of results;
- questioning, hypothesising, collecting data and forming conclusions.

Possible implications of these findings are suggested for the identification and fostering of budding young scientists.

EXAMPLE 2: Qualitative research

A piece of qualitative research was done by R. Paulson (Johannesburg College of Education) on the use of diagrams in fraction work at primary level.

Part of the research involved interviewing pupils. These interviews revealed a wide range of understanding and methods, not always evident from the written responses. Some children who had the correct answer for computational tasks, were found to hold basic misconceptions about the underlying procedures. The interviews were most instructive and a personal eye-opener to the researcher.

From the study it was evident that it is the way in which diagrams are being used that makes the difference in pupils' understanding of fractions.

6.4 Relevance of science and technology education research

Primary science, integrated and environmental science, and technology are some of the more recent innovations at the primary level of education. Teachers at this level are expected to put into practice the intentions of curriculum developers as specified in the various curriculum documents. In reality, observations of pupils' and teachers' activities in science and technology classrooms reveal that the intentions of curriculum developers are often reinterpreted by teachers to suit particular classroom contexts. Teachers face problems in putting curriculum specifications into action, and in making the far-reaching decisions expected of them in carrying out managerial responsibilities in the classroom. Teachers need opportunities to familiarise themselves with information on new curricula and on curriculum-related issues. This suggests the need for modifications in policy as well as in classroom practice, and of providing a focus for reflection to enable all parties to take appropriate decisions.

This is where knowledge of research findings and action research become relevant. Very often research findings have not been widely applied in classrooms because teachers have limited access to them. This limited access may also be the result of a lack of awareness on the part of science and technology teacher educators about research findings, or difficulty in understanding the findings and interpreting them for classroom application.

By taking advantage of relevant research findings, teacher educators can improve their own classroom practices and help teachers to improve theirs. This could ultimately lead to informed and improved policy decisions and better classroom practices.

In sum, what research has to say to science and technology teacher educators may be defined in terms of **feedback** providing a focus for further **reflection** and **action**. Case Study 1 illustrates this point.

CASE STUDY 1

In a recent study (Okeke and Inomesia, 1986), an investigation was carried out into primary science teachers' perceptions of the teaching of primary science in two states of Nigeria. It was found that:

- 37% of primary science teachers surveyed in the study were unable to state any meaningful objectives of Nigeria's Primary Science Core Curriculum.
- 59% considered teacher-centred activities indicated good science teaching.

This research raises issues for the pre-service and in-service training of teachers. The implications for teacher educators could be extended to similar research in teacher preparation in integrated science, mathematics and technology.

6.5 The science and technology teacher educator as researcher

Science and technology teacher educators, as researchers, are mainly concerned with gaining a better understanding of their own classrooms, so as to enable them to make informed decisions before, during and after teaching/learning transactions. Such improved understanding will lead to improved quality in science and technology teacher education. It is not sufficient for teacher educators' work to be studied solely by outsiders: they need to study their work themselves. As insiders, science and technology teacher educators have a more intimate knowledge of the setting, even though they see it in their own way. An outsider, who may be a colleague or research expert, is best used in a collaborative pact with the teacher educator, bringing specialist skills of 'seeing' and thinking about events.

The science and technology teacher educator as a researcher can collaborate with science and technology teachers at the primary level in order to understand and clarify aspects of the classroom situation at that level. The aim is to use the findings to improve science and technology teaching as well as teacher education. In such a research partnership, the roles and responsibilities of each partner could be as shown in Table 1. The teacher's role as researcher is rooted in their everyday practice in the classroom.

Table 1: Relationships and responsibilities in a teacher-development research partnership

Phases of research	Planning and preparation for research	Data-collection techniques	Analysis and interpretation	Report writing and use
Key actors				
Science and technology teacher educator	Primary responsibility for articulation of purpose, co-ordination of research and negotiation of activities	Identification and negotiation of possible strategies; primary responsibility for gathering mutually agreed information	Preparation and presentation of preliminary analysis; mutual interpretation of preliminary analysis leading to final analysis	Primary responsibility for writing account; responsive to teacher's editorial comments; perceived mutual benefit
Teacher	Negotiated participation in terms of perceived benefit, commitment and procedure	Identification of information sources and negotiation of appropriate strategies	Responsive to preliminary analysis; mutual interpretation leading to final analysis	Negotiated representation in report writing and editing of personal accounts; perceived mutual benefit

Source: Adapted from Cole, A. L. & Knowles, J. G. (1993) Teacher development partnership research: a focus on methods and issues. *American Educational Research Journal*, 30(3), 473–495.

When teacher educators are researchers, they are learners too. As learners, in their daily classroom activities, science and technology teacher educators have a responsibility to listen to their students' ideas and language, to assess their own teaching approach, to observe their students and to reflect on classroom transactions in an attempt to make changes that will improve learning.

Thus, science and technology teacher educators are, at least informally, carrying out **action research** – using classroom data to clarify curriculum and learning problems. As researchers, teacher educators develop problem-solving skills and a questioning attitude. This questioning attitude can further refine their data-gathering methods and analysis techniques and so improve the quality of teaching and learning.

6.6 Action research

Action research has been defined as '*research carried out by practitioners with a view to improving their professional practice and understanding it better*'. It is a form of inquiry centred on relevance and context to bring about change in practice. Action research involves trying out ideas in practice as a means of increasing knowledge about and/or improving curriculum teaching and learning. Collaborative action research with science and technology teachers helps to eliminate the isolation that has long characterised teaching, as it promotes

professional dialogue leading to the creation of a professional culture in schools. Collaborative action research can also assist teachers doing research for the first time.

There are a number of models for action research. Problem-solving projects are common forms of this type of research. Action research models usually involve a cycle of reflecting, planning, collecting data, trying out strategies, obtaining and analysing feedback, modifying plans in the light of feedback, and continuing on the cycle as summarised in Figure 1.

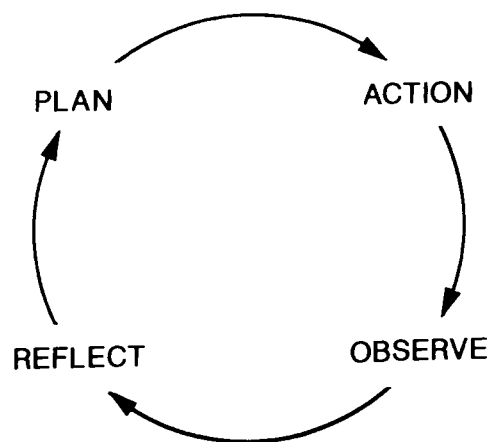


Figure 1

6.6.1 Characteristics of action research

Action research, like other types of research, seeks to increase knowledge and understanding of a phenomenon or event. However it differs from more formal research methods in a number of ways:

- Action research does not require extensive training in research methods. Teacher educators can carry it out on their own, in collaboration with another teacher educator, a research specialist or a teacher.
- The goal of action research is to obtain knowledge that can be applied directly to the situation being studied. It also helps to improve the teacher educators' performance.
- Problems investigated in action research are ones that teacher educators view as interfering with their efficiency or that of their colleagues.
- Action research does not require the rigorous literature review expected in more formal research. A literature review using secondary sources is usually adequate to begin with.

- Action research can use the students, with whom the teacher educators work, as subjects.
- Action research is flexible: immediate changes can be made to plans in response to the particular conditions of a situation.
- The tools used do not need to be tested in separate trials and reliability and validity established.
- Analysis of most action research data involves use of simple descriptive statistics instead of inferential procedures. The subjective opinion of the researcher is given prominence. The focus is on practical significance of the results rather than statistical significance.
- In contrast to formal research, where research findings are reported in terms of their theoretical importance, action research findings are reported to portray the impact of the findings on the science and technology teacher educator's work. They are also reported to inform other science and technology teacher educators about the implications of the research for professional development.

6.6.2 Focus areas for action research in science and technology education

Since action research is geared towards helping practitioners to study their own practice in order to solve their problems, the content of the research should be relevant to the teaching activities of the teacher educators and teachers.

CASE STUDY 2

Attracted to science: a close look at a primary science lesson

A single science lesson was video-taped in Guguletu for an action-research module of the BEd course at the University of Cape Town (UCT), by the Primary Science Programme, Western Cape (South Africa).

Teaching in large classes (1:55) through a second (or third) language as a medium of instruction (English), with insufficient science equipment, is common in the majority of primary schools. Hope for immediate meaningful change therefore depends on teachers taking responsibility for improvement.

In this case study, a series of group practical activities on the topics of magnetism, and measuring volume was conducted, giving pupils the opportunity to observe the features and properties of magnets and the measurement of volumes of liquids, so that they could develop a clearer understanding.

(Case Study 2 cont.)

Amongst other things, the following featured very strongly:

- pupils used a vernacular (Xhosa) during the practical activity to argue/explain/discuss the topic with each other;
- pupil activities served as a basis for thought and problem solving;
- the powerful role of the teacher as a mediator of learning.

This case study focused on a specific aspect of shifting the ownership of learning to the pupils. It resulted in the teacher shifting from his role as dispenser of information to a facilitator of pupils' own learning.

Research based on the activities carried out by science and technology educators and teachers can be classified into the following broad areas:

• **Students' learning.** This may involve using strategies to explore students' ideas about science and technology or identifying the problem-solving strategies of students. Areas such as pupils' misconceptions; questioning; designing and making; scientific vocabulary and 'second-language-science-learning' could be investigated.

• **Teaching strategies.** This may include trying out different approaches to teaching science and technology topics. For example, the teacher may be interested in finding out how he or she can help pupils to have a better understanding of the particulate nature of matter. The teacher educator may also be interested in finding out how a teacher or trainee teacher uses a teaching technique to which he or she has been introduced.

EXAMPLE

Does an alternative strategy to traditional practical work in schools, which is more cost-effective, achieve similar objectives?

Will participation in 'hands-on' activities help pupils to develop:

- a more positive attitude towards science practicals?
- an increased understanding of certain basic scientific concepts?
- designing and making skills?

• **Attitude.** This will include developing ways of increasing pupils' interest in science and technology and counteracting negative attitudes. It may also involve developing ways of increasing the involvement of girls in science and technology. For example: Is there a gender difference in pupils' enjoyment of practical work? What kinds of 'hands-on' activities increase the motivation of girls to study science and technology?

• **Assessment and evaluation.** Assessment and evaluation are integral parts of the educational process because they provide vital feedback about the extent to which the objectives of science and technology education are being achieved. The information obtained through assessment and evaluation can be used to take corrective measures. Teacher educators and teachers can conduct research on issues and problems related to assessment and evaluation, such as:

- good assessment practices for the measurement and evaluation of students' behaviour, ethics and values;
- techniques for assessing the skills of acquiring, organising and using information.

6.7 Promoting science and technology education research

As stated earlier, science and technology teacher educators are expected to conduct research for their own professional development, on their own, in collaboration with colleagues, teachers and with other researchers. Relevant research findings can have beneficial effects on their competence, on the content of the curriculum, and on the learning environment. They need to know how to initiate, execute and use research.

Science and technology teacher educators may obtain problems or ideas for research by:

- observing and listening to students and teachers in the classroom;
- obtaining feedback from research findings which may motivate them to initiate action research;
- reflecting on their own teaching procedure;
- observing and examining classroom teaching practice of trainee teachers;
- developing a habit of questioning and testing the ideas of other practitioners in the field;
- critically examining assessment results and assignments;
- critically reviewing research studies conducted by others.

This list is by no means exhaustive. However, for science and technology teacher educators to take a research approach to their teaching, they should be willing to examine their own practice critically and systematically, be able to identify discrepancies between the reality (in their classrooms) and what is considered 'good practice'. Such an approach requires open-mindedness on the part of teacher educators.

6.7.1 Why a research proposal?

Once a research idea has been conceived, or a problem identified for research, it is good practice to write it up as a research proposal.

Apart from possibly being needed for an application for funding or a proposal for studying a higher degree, writing a formal research proposal can also serve to focus attention on:

- clarifying and stating the problem;
- clarifying the objectives of the research;
- identifying the population, sample and procedure for collecting and analysing data;
- specifying the individual activities in the study and when to perform them;
- identifying the materials required for the study;
- estimating the cost of the various aspects of the study.

A written research proposal also allows the researcher to receive feedback from colleagues on the clarity with which the problem is presented, the procedures to be used in the study, and on the relevant literature available.

6.7.2 Writing a research proposal

Science and technology teacher educators need to develop the skill of writing research proposals, as part of their professional responsibilities and development. A research proposal is a systematic description of the researcher's whole plan of action designed to collect the data intended, resolve the problem, provide an answer or demonstrate a need for further research.

The basic elements of a research proposal are:

- **The title.**
- **An introduction and background to the study.**
- **Identification of the problem** to be investigated – a precise statement of the problem or purpose is needed.
- **Identification of research questions or objectives** arising from the problem statement, and the hypothesis, if any, to be tested.
- **Details of the research design and procedure**, describing the activities that would lead to the attainment of the objectives – answering the research questions or testing the hypothesis. These should include: identification of target population and sample, and instruments/materials to be used; phases of the activities, their components, methods or procedures for collecting data and techniques for data analysis.

- **The time schedule.** This should give an indication of the starting date for the research, when it will end and the timetable for the different phases.
- **A budget.** This gives an indication of how much the research will cost. It should be detailed and comprehensive and should include all items of expenditure and the total amount required.

6.7.3 Writing a research report

One of the most important aspects of a research study is communicating the results to others. Research reports are means of documenting and disseminating research information. Science and technology teacher educators and their students need to be conversant with the skills of writing research reports.

There are many formats for writing reports but there is general agreement on the format detailed below.

- **The title.** The report must start with a title. The title must clearly indicate the subject of the research to the reader.
- **The abstract.** After the title comes the abstract, which contains the important ideas and main steps of the study. It is a brief summary of the whole study and should include a statement of its purpose, the type of subjects used, brief statement of design, data and analysis techniques, results and findings. The whole should be no longer than three-quarters of a side of A4 paper.
- **Statement of the problem.** The statement introduces the reader to the problem which should be clearly described. If research hypotheses were formulated, these should also be included in this section of the report.
- **Literature review.** This summarises the researcher's critical appraisal of relevant published material, which highlights the need for the study. It also provides a theoretical framework for the study.
- **Design and procedure.** In this section the researcher should clearly explain the following aspects:
 - the nature of the design including the sample: whether it is a descriptive survey, correlational or experimental design; the characteristics of the samples, including number, sex, age-range, class or form, and sampling procedure.

- the instruments, such as questionnaires, rating scales, tests, etc., which served as the main tools for obtaining data, including the name of the instrument, complete details of its source, and psychometric characteristics such as reliability and validity information;
- the procedure followed to conduct the study: a detailed step-by-step description of how it was carried out.

• **Results.** There are many ways of presenting results depending on what they are, how they were collected and what they are intended to show. Tables, graphs, lists or figures should be used where possible to help present results clearly, and referred to in the account of the results. All tables, charts, graphs and terminology used should be clearly explained so that they help the reader to understand the report. Where statistical tests of significance have been indicated, it is useful to include all formulations that led to the rejection or acceptance of the stated hypotheses. In qualitative research, a detailed description of observations made, including some of key statements made by the source of data, should be included.

• **Discussion of results.** In this section the results should be carefully explained (of course within the limitations of the study), question by question or hypothesis by hypothesis. Part of the discussion should include explanations of the results within the context of existing knowledge of the problem. Do the results contradict or corroborate other findings? Or do the results stand out clearly on their own? Are there unexpected results? – Why? Here the researcher should explain, argue and possibly make predictions based on his or her findings. This is the section for the researcher to propound his or her views.

• **Bibliography and references.** The bibliography is a list of the publications studied by the researcher. Quotations or particular references to other work in the report are listed under 'References'. If the report is intended for publication in a journal, the author should refer to that publication and follow their style for setting out the references or bibliography.

As well as teaching their students the skills of writing research reports, science and technology teacher educators themselves should put these skills into practice.

6.8 Recommendations in support of research in science and technology education.

• **Research data banks.** To promote research in science and technology it would be immensely helpful if data banks were created where research data could be stored and made available to researchers to support action research. The data bank could also provide researchers' and teachers' research findings for use in their research/teaching. The

Commonwealth Secretariat may like to support the establishment of such banks and their networks.

- **Workshops in action research.** Many science and technology teacher educators working at the primary level do not have enough experience of research. They do not lack knowledge of research problems and issues but they lack competence and experience in research methodology. It would be very useful if workshops could be organised for teachers and teacher educators to develop their skills of research methodology. This would help promote action research. The Commonwealth Secretariat may like to support such training programmes or conduct workshops in member countries.

- **Private sector involvement.** Education authorities, industry, public and private sectors should be called upon to encourage and support research.

- **Regional clearing houses.** Science and technology research materials, such as research reports and evaluation instruments published in the local language, should be collected in regional centres. Many educational institutions cannot subscribe to journals. Ways should be found to make journals available to educational institutions doing research.

- **Networking.** Networks of researchers and institutions conducting research in science and technology should be established.

- **Dissemination.** Mechanisms should be set up for the dissemination of research information, particularly at the local level.

- **Support mechanisms for novice researchers.** Teacher educators of primary teachers generally lack research skills. To promote research, teacher educators need training in research methodology. They also need support at different stages of research through the establishment of suitable mechanisms. The establishment of research advisory committees could be one way forward.

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