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, bottletops, 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.