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 Key actors	Planning and preparation for research	Data-collection techniques	Analysis and interpretation	Report writing and use
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.

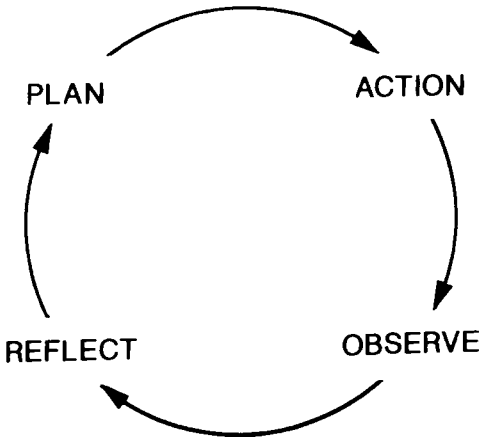

Figure 1

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 of 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.