CHAPTER 6: TEACHER EDUCATION STRATEGIES IN THE INTERRELATED TEACHING OF SCIENCE, MATHEMATICS AND TECHNICAL/ VOCATIONAL CURRICULA

S. Commissiong and B. Carlisle*

Introduction

Educational development, at the present time, is characterised by two main aims: to enhance the content of education by making it more relevant and to improve the teaching/ learning process.

In science, both these aims have given rise to a number of projects which have attempted to link together the concepts and principles into a unified or integrated whole. The curricular materials generally include materials (texts and kits) for the students and guides for the teachers. Often these are so closely tied to the particular curriculum that teachers not directly involved in the project concerned have been only marginally influenced. It has also been observed that when the trial phase of the new curriculum (during which intensive training of teachers takes place) is over, many teachers find it difficult to sustain the rhythm of implementation for a variety of reasons. Much lip-service has been paid to the fact that teachers are agents of change and that central to any development or innovation is the role that they must play in bringing about that change, but little has been done to develop a theoretical framework in support of this role.

Much teaching in the past emphasised content. Today the shift away from teaching facts to teaching skills poses a challenge if not a threat to all who are engaged in the enterprise.

Teaching is essentially a process of developing, clarifying, enlarging and presenting information, ideas and meanings to others. Its ultimate aim is that of preparing pupils for life in the real world. The qualities and skills necessary to do this effectively is still a matter of considerable controversy. However, certain characteristics seem to be agreed upon as part of the reservoir of skills and dispositions that a teacher should possess. These include:

- faith in the ability of people to change;
- an ability to see thematic consistencies in diverse information with skill in organising and communicating these differences;

---

*Contributing author

- an ability to conceptualise many sides of a controversial issue;

- an ability to learn from experience;

- empathy;

- well developed cognition;

- personal motivation, enthusiasm and conviction;

- maturity.

Much depends on the teacher's ability to manipulate the classroom situation, which in turn depends on how much he knows of his subject areas, how much he understands children's needs in relation to those of their society, and how flexible he is and open to change.

In the planning and implementation of any teacher training programme, consideration must also be given to the needs and concerns of the student-teacher and to the fact that teaching styles are as diverse as learning styles and that the needs of the teacher change with time.

Interrelated Teaching

There is no precise definition of interrelated teaching but the term does imply some form of linking of bodies of knowledge together in a meaningful way. The real difficulty lies in locating the organising centres of such an approach.

There are three possible approaches to interrelated teaching: interdisciplinary, multidisciplinary and transdisciplinary. The first two use the subject or subject matter as focal points whilst the third uses situations as a basis for organising the learning. There is virtue in using all three approaches with the aim of giving students a functional knowledge of the interactions between the different factors and components and the constant evolution of the natural and human environments of which they are a part. Organising teaching so that subjects are interrelated is a complex undertaking, the magnitude of which cannot be overstated. While situations may be used as the organising centre of the curriculum thus focusing on the learner, there are advantages in not completely discarding the classification of knowledge into disciplines. Disciplines have their own method and epistemology, and by the very nature of their specificity should be treated in such a way so as to preserve their impact on the systematic training of the mind. There is good reason for

retaining them at the secondary level though every effort should be made to de-emphasise the teaching of information as an end in itself and to interrelate subjects by drawing on the various methodologies and explanatory theories of the disciplines concerned.

What do Interrelated Studies Demand in Teacher Training?

Interrelated studies demand intellectual breadth, knowledge and insight from both college tutor and the teacher trainee in training. In any cultural setting interrelated studies in schools will contrast sharply with the status quo, the expectations tutors and students have of teaching, and the popular concept of schooling, its goals and outcomes.

The nature of the change presupposes a number of conditions. These may be summarised as follows:

1. Each teacher trainee has experience of a knowledge structure which interrelates the various disciplines. The experiences of childhood are not gathered into a knowledge system recognisable as disciplines. The interests of childhood and the knowledge gained do not recognise the boundaries of disciplines, at least in the early years. Knowledge is gained from action. Children's thinking flows easily from a preoccupation with factual information to flights of fantasy, moving easily from reality to imagination. The world is one whole, a seamless fabric explored through observation, questions and 'experiments'. Hand and brain work together in an effort to satisfy curiosity and assure survival. The extent and depth of the knowledge structure is greatly influenced by ability, social class and schooling.

   Each student has had experience of this interrelated mode of learning in their early years and developed a knowledge structure shared by siblings and comrades within a culture. This memory can be evoked or recognised by observation of children in school. Individuals therefore do not come as strangers to interrelated studies. Indeed it can be argued that these early constructs are the basis for the more formal work of later schooling.

   Many young adults have also developed interests and expertise within the pursuit of a hobby in which knowledge is built up in a non-linear way. Such knowledge also stretches across the boundaries of many 'discipline' fields. The natural occurrence of

interrelated studies in the informal learning setting of clubs, museums, art and science centres for both children and adults provides a useful model of observation of interrelated knowledge in action.

2. For most students interrelated studies demand a change in "experiences", that is, a change in the belief structure rather than a change in educational technique (pedagogy). This second assumption would seem to contradict the earlier one and present a paradox. Every student has earlier experiences of interrelated studies, but these are later challenged. The expectation of school is expressed in terms of what is taught and how it is taught. School is a place where one learns "subjects", where time is regulated by succeeding applications of mathematics, science, social studies, art, etc. and where knowledge exists within recognised disciplines. Success is measured in terms of achievement in examinations rather than in terms of the intellectual skills gained or the ability to transfer these skills to everyday life. The accent is on knowing that rather than on knowing how. Conversion to another view of schooling will of necessity be slow and difficult to achieve, for while an interrelated approach is accepted in primary and middle school there is often a resistance to it at the secondary and tertiary levels.

3. Science, and its mode of operation is in conflict with traditional thoughts, and will demand a change of view at both the personal and professional levels. The individual develops from having a simple concept of the world, its physical, chemical and biological "laws" to an increasingly complex and "open" view of nature. While this may be true to some extent in any culture, western societies in general are more supportive of the "open", "scientific" viewpoint even though not all members of the society practice it. Given this premise it is likely that interrelated studies will present a challenge to an established way of thinking and will demand a change of view of many students.

4. Through the teaching of interrelated studies it is believed that students will develop a knowledge structure relevant to experience and readily adaptive and transferable, and a diversity of concepts developed within the context of 'need to know' rather than a formal discipline. In the days of pre-formal schooling the culture was learned through example, observation and practice, and crafts were

learned by apprenticeship to skilled practitioners. By this apprenticeship, knowledge, skill and techniques were acquired as needed and established through continued practice. The awkward and untutored early efforts gradually progressed towards a natural integration of mind and muscle. The knowledge structure was thus organised according to need and practice.

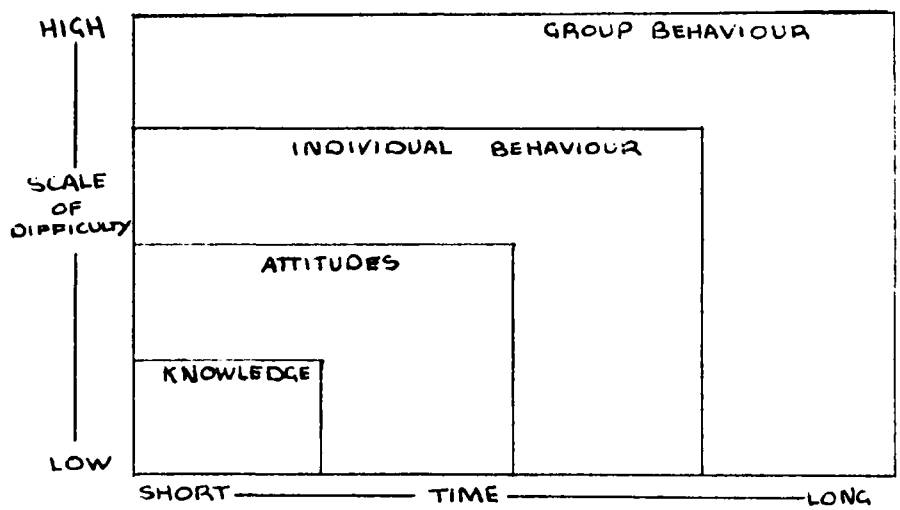
Many parallels between the informal learning environment of childhood and the more structured apprenticeship or adult learning as evidenced in a hobby or avocation can be established. In a hobby such as, for example, photography, knowledge is gained in a non-linear way, the extent and depth of that knowledge being sufficient to solve current problems. The knowledge base is extended when new problems are met. The skills developed are found to match the demands of the task. The individual progresses at his own rate. He controls the rate of his learning and so maintains a sense of competence. This sense of control and the pleasure gained sustain the learning process, ensure attention and perseverance, and maintain curiosity. Repetition of tasks to the point of mastery is a characteristic, often accompanied by overlearning to the stage where understanding is complete and performance of the skill automatic.

This non-linear progression of learning is quite unlike the sequence which would be presented in formal instruction. Knowledge gained by non-linear progression resembles an incomplete jig-saw puzzle, with many gaps, but with many places where the picture can be seen clearly. The jig-saw puzzle analogy can be expanded into a three-dimension model which allows for cross-linkages between pieces while at the same time supporting the idea that there are areas of knowledge which exist in isolation within the matrix.

5. Supervised practice in conducting interrelated studies in schools is a prerequisite to effective teaching. Knowledge built up in this way is highly adaptive, has cultural relevance and is readily available for use or for review. Learning in interrelated studies has these characteristics, but time will be required to facilitate the over-learning necessary to sustain involvement and develop competence.

6. Young teachers need support in schools in order to introduce and maintain interrelated studies. In summary, interrelated teaching demands a change in attitude and behaviour, both requiring time, and a support system which extends beyond the training period. Figure I shows the relationship between scale of difficulty and time.

Figure I Relative Time and Difficulty in Making Changes



Training of Teachers for Interrelated Teaching

In considering strategies needed, it will be necessary to distinguish between pre-service and in-service programmes as well as between different levels at which teachers will be teaching. Allowances should also be made for those programmes which are end-on-courses and for those in which pedagogy is combined with subject content. It is assumed that any programme will include the professional areas of Philosophy of Education, Sociology, Educational Psychology.

1. Organisation of the Content:

As a general aim, the teacher required to teach science related to the fields it services should have the kind of science background that reflects what science really is, a willingness to be innovative, and certain competencies which include:

- a thorough knowledge of at least one of the sciences and a basic understanding of its interrelationship with the technical and vocational fields - for the primary teacher a broad background in the sciences (integrated science preferably) with skill in relating it to art and craft and to the rudiments of other areas in the technical and vocational fields;

- an ability to select and develop or implement curricular materials and strategies leading to desired behaviours in the learner;

- an understanding of the cultural values inherent in scientific activity;

- an appreciation of the role that mathematics plays in the understanding of reality;

- an appreciation of the value of indigenous cultural roots;

- competencies in a variety of teaching-learning strategies and techniques including evaluation aimed at promoting the development of enquiry skills in the learner;

- open-mindedness and flexibility in personal style that accommodates coping with change.

Since student teachers will be entering the course from a variety of backgrounds and interests, it would be desirable to structure the content in the form of modules to allow for different entry points and to facilitate alternative routes through the programme.

A common core of knowledge based on the 'big ideas' or conceptual schemes of science may serve as the main branch with off-shoots leading into the technical and vocational fields. For example fuel, energy, machines, shape and pattern, materials and structures, nutrition, health, time and space, conservation are some of the universal topics that may be used as major themes for interrelated studies.

The materials chosen for curriculum development should interrelate varying bodies of knowledge, reflect the world of work and be based on the 'scientific' approach. Students should learn in ways that they can themselves use when teaching.

There are three levels of curriculum materials:

Level 1: Individual challenges
Level 2: Thematic challenges
Level 3: Integrative challenges

These levels, which are arranged in hierarchical order, are aimed at developing creative thinking, one of the attributes required for interrelated teaching. Creative thinking may be said to comprise the ability to recognise problems, produce novel ideas, organise ideas and evaluate the results.

Examples of these three levels of curriculum materials are:

Level 1: Individual challenges

Specific but small-scale challenges such as to design and use a trap to capture small animals (insects, mice), or to camouflage an object (e.g. a pebble) so that it will be difficult to find.

These challenges incorporate thinking and manipulative skills. All demand knowledge of the phenomena to be investigated, require some quantification and engineering-type design, and often relate to everyday life situations. Each challenge embodies understanding at both the level of first-hand experience and at a conceptual level.

Level 2: Thematic challenges

Individual work is replaced by group activity with problem-solving in a social context. For example, strength of materials can give rise to many interesting problem-solving ideas, e.g. to design and construct a bridge 40 cm long to hold at least 1 kg using only 150 wax paper drinking straws and an unlimited supply of straight pins.

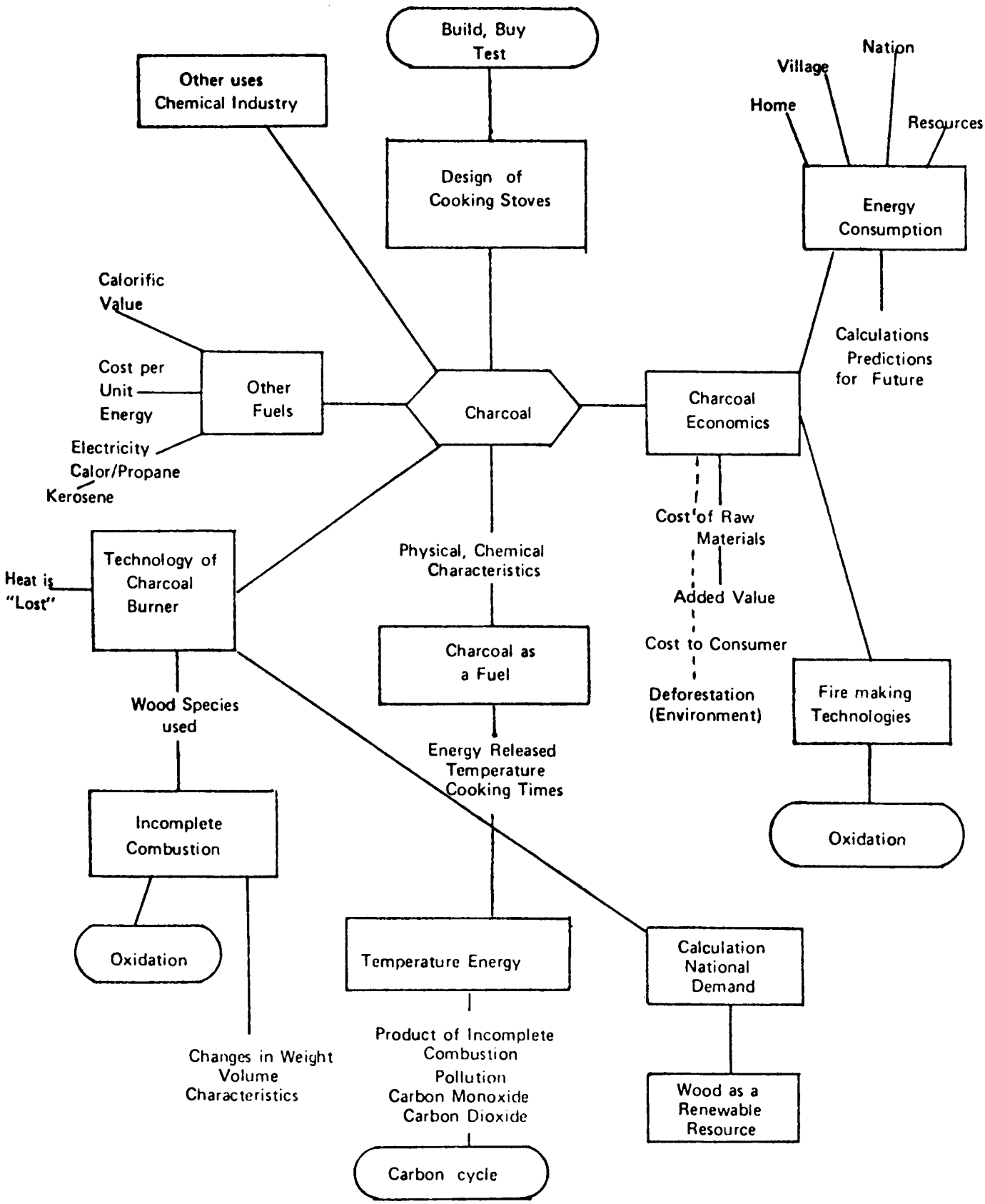
Level 3: Integrative challenges

This is the most complex array of challenges and is integrative in the widest sense of bringing together ideas which are from varying fields of human knowledge, thus providing for both tutors and students an opportunity to build a network of themes relevant to local conditions.

One example, shown in Figure II, is Charcoal, an Interrelated Unit.

FIGURE II

CHARCOAL - An Interrelated Unit



2. Strategies of delivery

How is information acquired and presented? A proposed strategy involves team teaching across subject boundaries as a method of presenting the teacher trainee with information through lectures, demonstrations, projects, seminars and workshops. The student-teachers will, however, play an active role - selecting topics and materials - rather than the passive role of receiving information.

For team-teaching to be successful, a knowledge of group dynamics which allows the easy flow of communication between members is essential. Techniques of delivery include team and peer group teaching, micro-teaching, the use of video-taping, cassette tape recording and other self-teaching devices.

The ability to read and communicate information is part of the cognitive behaviour of a scientist. Uniformity in the use of symbols across the disciplines is advised since it will have the advantage of aiding interrelated teaching by reducing confusion. Teachers should have an introductory course in the teaching of reading with particular reference to science and interrelated subject areas. If part of the education course is to teach individuals to plan and to write curriculum materials for different age groups and abilities then this skill is mandatory.

Training also in the various modes of communication should be incorporated into the strategy. Tutors themselves should demonstrate the potential of the various methods in the teaching-learning situation.

3. Strategies of evaluation

Feedback mechanisms designed primarily for diagnostic rather than achievement purposes would seem to be appropriate for the task of evaluation. Teachers need to develop confidence in their own ability to teach in the new way and to evaluate themselves. They should be willing to make mistakes and be free to experiment with a variety of approaches in the classroom. Far too often the student-teacher perceives the practice teaching as a test situation the purpose of which is the awarding of a grade. The emotional stress involved needs to be reduced if the teacher is to be innovative and acquire self-confidence.

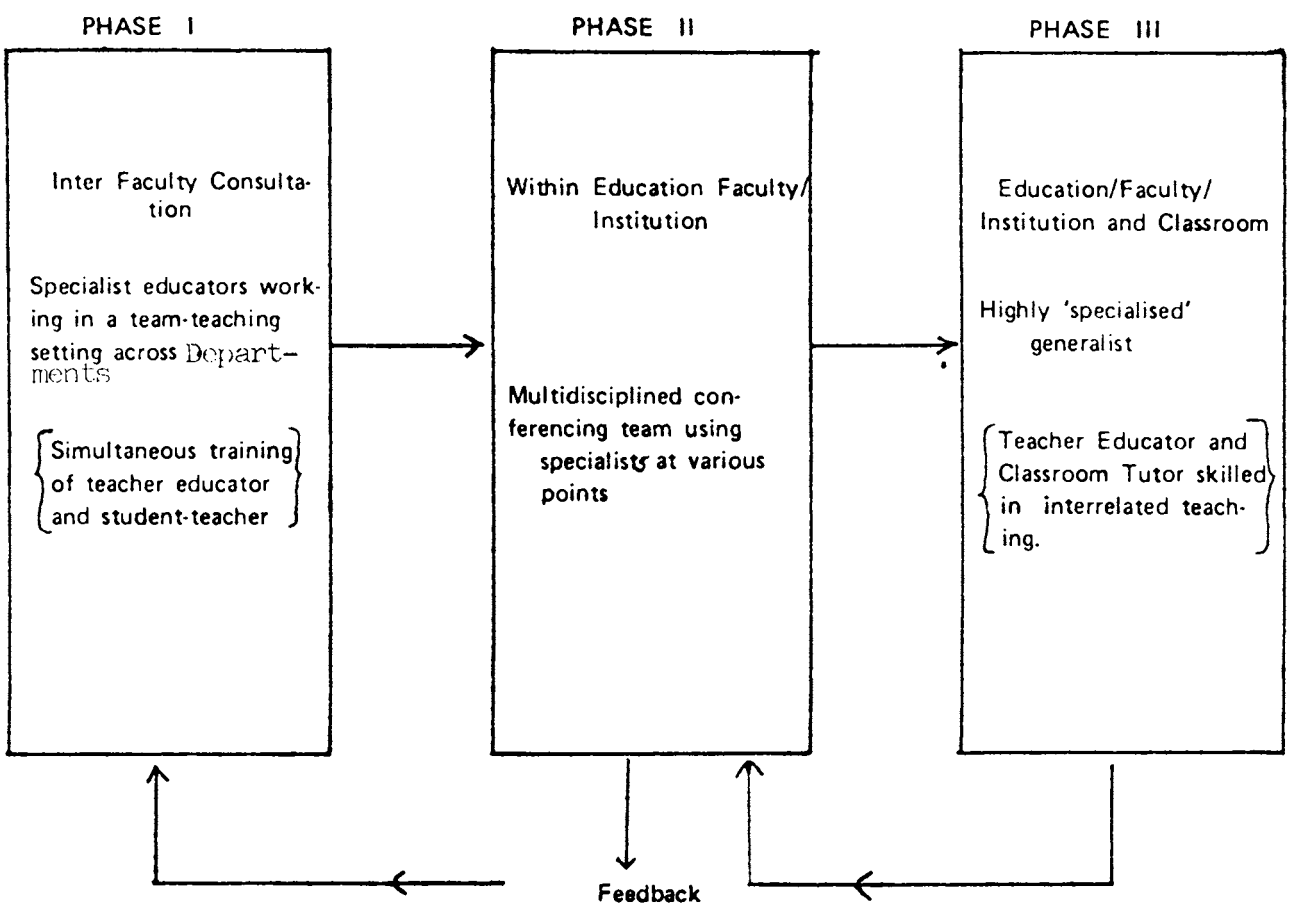
Continuous assessment through written papers, laboratory work, project work including designing curricular units, making equipment from local materials, micro-teaching and peer group assessment are desirable. A credit system using profile ratings is recommended since these have the advantage of highlighting each facet of the multidimensional strengths which the new approach demands.

4. Implementation

Teaching in an interrelated manner will require a reappraisal and restructuring of the educational system. At the secondary level it will mean a radical change in which early specialisation in the disciplines is postponed until the age of 16+ years.

Teachers play a central role in curriculum change. Not only will the proposed change affect pre- and in-service training programmes but a massive retraining of teachers will be necessary if the idea is to survive. Implementation is envisaged in stages or phases as interrelated teaching evolves (see Figure III).

FIGURE III



Without practice and support little can be achieved in the long-term. Guided experience in college at student level and guided experience in schools will be required. Working in college will provide a base in content, a pedagogic model and some sense of security and competence. However, college level work, important though it is, will not be sufficient to bridge the transition into schools. Students need to work with children in classrooms so they can see the mechanisms of classroom management, and experience a working model that will provide an examplar for further work. The traditional approach whereby one college student is limited to one classroom might not be the best method here; two or more students working together tend to provide a common experience for co-operation, discussion and debate.

It is likely that early experiences in the classroom will be based on work already carried out at college. For many students, the replication of such work will mark the maximum that can be done in schools. However, for the more able students the conception, and development, of 'new' interrelated studies for implementation would seem to be a legitimate goal. Like the agriculturalists we should help people 'grow food' rather than provide 'food'. These proposals suggest that the methodologies at college and school should be similar but should acknowledge the age difference and level of development of the student-teacher.

5. Implications

It is expected that interrelated teaching may well disrupt the educational system. However, the simultaneous training of teacher educator and student-teacher together with the cross-fertilisation provided by team work across Departments should act as stimulants rather than deterrents. Secondary school time-tables will need reorganisation.

Since examinations have a powerful influence on teaching methods it may be possible to capitalise on their influence by modifying them to include a school-based assessment component in the form of projects. Some Examination Boards are already using this mode of assessment.

There will be need for closer links between the tutors of technical and vocational subjects and science and mathematics. At the moment, there is a tendency to view the technical-vocational subjects as inferior to science and mathematics. The areas of study should be seen as complementary. If tutors themselves make a conscious effort to work together as a team it is highly probable that the artificial barriers will begin to break down.

The science teachers' education programme should be extended to include a basic technician's course as well as skills in laboratory management with the accent on the use of indigenous materials and the making of low-cost equipment.

References

Brown, W. S. The Design of the Informal Learning Environment. Paper presented to Annual Conference of the Canadian Museums Association in Vancouver, May 30, 1979

Czikszentmihalyi, M. "Intrinsic Motivation and Effective Teaching: A flow Analysis", Best, J. L. (ed.), Motivating Professors to Teach Effectively, Jossey-Bass Inc., San Francisco, 1982, pp. 15-26.

Czikszentmihalyi, M. Beyond Boredom and Anxiety, Jossey-Bass, San Francisco, London 1975.

D'hainaut, L. "Interdisciplinarity and Integration" in Curricula and Lifelong Education: Studies for UNESCO, pp. 201-229, UNESCO, Paris, 1981.

De Vito, A "Recognizing and Assessing Creativity" in Developing Teacher Competencies, J. E. Wiegand (ed.), Prentice-Hall Inc., Inc., Englewood Cliff, New Jersey, 1971, pp. 208-245.

Ducharme, E. R. and Mash, R. J. "Preparing New Educational Professionals for Non-Public School Setting" in Journal of Teacher Education, XXXIX (4): 36-41 (July - August 1978).

Glean, C. A. "Social Studies Teacher Education: Towards a Rationale and Process for the Eastern Caribbean" in Caribbean Journal of Education, 6 (3): 221-241 (1979).

Horton, W. R. G. "African Traditional Thought and Western Science", Part II "The 'Closed' and 'Open' Predicament", Africa, Vol. 37, No. 2, 1967, pp. 157-87.

Koran, J. J., Longino, S. J., Curiosity Behaviour in Formal and Informal Settings: What Research Says. Bulletin prepared for the Florida Education Research and Development Council, Sanibel, Florida, March 1982.

Malone, T. W. "What Makes Computers Fun?" Byte Magazine, Vol.6, No. 12, December, 1981, pp. 258-77.

Malone, T. W. What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games. Technical Report No. CIS-7 (SSL-80-11), Palo Alto, California: Xerox Palo Alto Research Centre, 1980.

Morrich, L. Aspects of the Education Change, George Allen & Unwin Limited, London, 1968.

Papert, S. Mind-Storms: Children Computers and Powerful Ideas. Basic Books Inc., Publishers, New York, 1980.

Pitz, A., and Sund, R. Creative Teaching of Science in the Elementary School, 2nd Edition, Allayne and Bacon Inc., 1974, pp. 7-9.

Posner, G. J. and Gertzog, W. "The Clinical Interview and the Measurement of Conceptual Change" in Science Education, 66 (2): 1982, pp. 195-209.

Pring, R. Knowledge and Schooling. Open Books Publishing Company Limited, Somerset, England, 1976.

Rogers, E. M., Shoemaker, F. F.: Communication of Innovation: A Cross-Cultural Approach, Collier-Macmillan, London, 1971.

Waring, M. Social Pressures and Curriculum Innovation. A Study of the Nuffield Foundation Science Teaching Project, Methuen and Company Limited, London, 1979, pp. 10-11.

Warwick, D. Integrated Studies in the Secondary School, Warwick, D. (ed.), University of London Press Limited.