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Science Teaching in Open University System

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This is the third article in the science-related trio presented in this number. The first two pertain to medical education, while this one deals with the teaching of sciences in general. One who is upto date with the happenings in the world of distance education is bound to consider this presentation dated, but our experience with the Indian situation, characterised by unbelievable variations in awareness and deeprooted biases against innovations, suggests that we may yet be benefited by this piece. How we may achieve the general aims of science courses, develop scientific attitudes, improve our techniques of scientific enquiry and inculcate a scientific temper using distance education methodologies are some of the issues touched upon here.

The Indian distance educators have yet to make their presence felt in the area of the teaching of sciences. Is there anything here for them to think about? for them to work on? and to question about?

1. INTRODUCTION

Many people are sceptical about teaching science through the open university (OU) system as the teacher and the taught are spatially separated in this system. This is mainly because this system is equated by many of us with correspondence education and also partly due to our failure to recognise the recent developments both in theory and practice of educational technology. In fact, these advances, mostly by-products of the advances in communication technology, may even close the gap between conventional and open-learning provisions (Lewis, 1989). It is no longer true to state that distance education systems and open universities are unsuitable to the development of practical or interpersonal skills (Cohen, 1986; Everiss, 1984; Dobson, 1989). It is rather pertinent to consider which combination of educational and communication technologies will suit which subject and how best one can achieve the set educational objectives. These open learning technologies are already successfully implemented all over the world in different open universities for a range of subjects including sciences and other subjects with a practical orientation (Reddy, 1986).

The aims and objectives of science courses in an open university are achieved through a range of teaching strategies and activities which are discussed in this article in the light of the general aims of science courses. However, the points made or the examples cited may not be sufficiently exhaustive to represent all that is practised today; they are aimed at a general exposition of how science teaching is possible in an open university system.

2. GENERAL AIMS OF SCIENCE COURSES

The aims of science courses in general (Klopfer, 1971; Ziman, 1978; Boud et al., 1986) can be categorised under three broad heads as given below :

AIMS

i. Scientific Knowledge	ii. Scientific Skills
Knowledge and comprehension	Practical and manual skills*
Process of Scientific inquiry	Attitudes and interests
Application of Scientific knowledge and methods	Orientation

* Manual skills include lab and field techniques and handling of instruments

iii. Scientic Attitudes
Objective approach to a problem
Interest in the natural phenomena
Curiosity and relevant questioning
Orientation towards scientific method of enquiry

These aims and attitudes are interlinked and inter-related in any system of science education and the assumption is that face-to-face education does achieve them fairly successfully. Our concern here is to suggest ways of achieving them in the open distance education system. We shall take up the discussion under two headings:

Preparing learners for scientific thinking

Preparing learners for laboratory work

3. PREPARING LEARNERS FOR SCIENTIFIC THINKING

Learning to think scientifically (i.e. as a Botanist or a Chemist or a Paleontologist) is a long and complex process. It needs learner's attitudinal changes with regard to cognitive, psychomotor and affective domains, besides his/her acquiring a masterly facility with scientific processes (see Table 1) in the course of learning.

Table 1 Scientific Attitudes and Processes for Developing Scientific Temper — the lists are not meant to be exhaustive

SCIENTIFIC ATTITUDES	SCIENTIFIC PROCESSES
* intense curiosity	* identifying problems
* humility	* observing
* skepticism	* classifying
* determination	* measuring
* open mindedness	* hypothesizing or predicting
* objectivity	* analysing
	* inferring
	* extrapolating
	* synthesizing
	* evaluating
	* constructing principles, laws and theories

In open universities this is achieved through the multi-media approach, with the print medium as the major component in most cases. These media are used to help the student not only in gaining knowledge but also in acquiring the faculty of scientific inquiry and practical skills.

3.1 Promoting Knowledge and Comprehension

Since the study materials in the open university system have to take on the role of teachers as well, they are made more interactive in order to facilitiate easy transmission of knowledge to the learner. A variety of teacher functions like structured presentation of the subject-matter, motivating the learners, illustrating the complex concepts, giving parallels, dividing the content into small chunks, providing learner activities and summaries etc., are carried out by the study materials (See DE-3, IGNOU, 1988). In addition to these features, in the case of science subjects, the materials are enriched to help the learner in acquiring the scientific temper; as far as knowledge and comprehension in general are concerned provision is made for devices which promote

* acquaintance with the conceptual foundations of the subject
* understanding of the logic of the theme and
* grasp on the contemporary paradigm of a discipline so as to make judgements on the adequacy of the fit between theory and experiment.

When scientific knowledge is to be imparted through the print medium, sequencing of subject content assumes a prominent role. Besides, following the traditionally well known rules for sequencing (Davies, 1981) like proceeding from the known to the unknown, from the simple to the complex, from the concrete to the abstract, from observations to generalizations, from the whole to the parts and from the parts to the whole, new and different approaches to sequencing are developed on the basis of the purpose and objectives of the course (see Table 2). This kind of sequencing guided by purpose/objectives can help achieve the various objectives in gaining knowledge and insights.

Table 2: Categories of Sequencing - Knowledge and Comprehension

(adapted from Boud et al., 1986)

Category	Purpose	Objective of knowledge and comprehension
World-related sequences	spatial relationships; relationships in time; physical attributes.	conceptual foundations
Concept-related sequences	class relations (common properties); propositional relations (theory-evidence, rule-example, precise conclusions);	conceptual foundations
	sophistication (levels of abstract ness of ideas); logical prerequisites (necessity to learn one idea before another).	contemporary paradigms
Inquiry-related sequences	the logic of inquiry; the methodology of a given area.	logic of the subject
Learning-related sequences	empirical prerequisites; familiarity; difficulty levels; interest; internalization.	conceptual foundations
Utilization-related sequences	procedures for solving problems or fulfilling responsibilities; the extent to which a particular element of the course will be subsequently used	adequate fit between theory and experiment

Some of these approaches to sequencing are also likely to help the student in imbibing the scientific attitudes listed in table 1. Besides, appropriate choice and adequate use of teacher and/or learner activities, listed in table 3, help students get engaged in working through the course with ease, understanding and interest.

Table 3: Some Activities through print that may help in achieving aims of Knowledge and Comprehension in Science Courses

Objective	Teacher Activities	Learner activities
Imbibing curiosity	starting with some simple activity; relating it to a life event.	in-text questions; local examples
Introducing a concept	relating it to some well known concept; giving examples.	self-assessment questions
Understanding the logic of the subject	graphs; illustrations; concept maps.	concept maps; exercises on sequencing; intriguing in-text questions.
Grasping-contemporary paradigms	historical evolution of a theory/principle; giving concept maps; showing relations between different concepts & theories.	completing a concept; case studies.
Teaching vocabulary and technical terms	giving the origin of words; giving the original meaning (other languages); explaining the original meaning.	crossword puzzles
Judging on adequate fit between theory and experiment (objectivity)	some simple activity involving the application of a concept	self-assessment questions; work sheets.

The activities given are only representative samples and not exhaustive. A single activity may achieve more than one objective also.

*(*An in-text question is a question presented within the text. One of its purposes is to make the student think before he proceeds further. Usually the relevant explanation is given in the text itself).*

Other media, particularly the electronic media, are of immense help in transmitting such concepts as are difficult to visualise when presented through print. They are also useful in projecting real life situations, explaining difficult concepts by means of graded diagrams or visuals, displaying data diagrammatically, highlighting key features, showing long term processes, showing complex processes in slow motion, providing immediate feedback and the like. These possibilities and practices make it easy for the learner to acquire knowledge and comprehend it in the shortest possible time.

3.2 Promoting the Process of Scientific Inquiry

A variety of teaching strategies other than laboratory work are introduced to achieve various objectives specific to the study of sciences—observation and measuring, hypothesizing or predicting, analysing, inferring etc. Through the print medium, this is achieved by incorporating different activities in the study materials. Presented below are a few illustrative teaching strategies with suggestions to use them to inculcate the process of scientific inquiry in the learners.

Giving Examples

— Observing from daily life activities : The concept of genus and species in biology can be brought in gradually from how we classify different items in our daily life and from how we see differences between different types of plants.

Similarly the example of 7 notes of music can be brought in to explain the periodicity of elements of similar characteristics in the periodic table of elements.

— Observing and analysing similarities/dissimilarities relating to some well known concept : For example, observing fermentation of our daily food items can help the student understand the concept of microbiological conversions.

Using Common Experiences

— Inferring and formulating generalizations : The phenomenon of souring of curds and preparation of wines can be given as cases to infer and formulate generalizations to comprehend the concept of fermentation.

— Inferring and evaluation : In a lesson of fossil fuels a diagram showing the changing pattern of major sources of energy over a period of time can be used to make the student infer and evaluate the historical context of our present day fuels.

Giving Exercises

— Evaluating data in the light of alternative hypothesis: In a course on 'Genes and development' offered by UK Open University, data on changes in foot-pad cells of the fruit-fly are given. The data are followed by two hypotheses. Then, a series of questions asking for relationship between the data and either or both of the hypotheses is given as an exercise.

— Data gathering, hypothesis-formation, testing and confirmation/rejection of hypothesis : In a UKOU Biochemistry course an exercise on enzyme activities is used to achieve these objectives.

— Interpretation of results : For example, a puzzle on mealworm with a series of diagrams showing the response of mealworm to moisture and light can be used to achieve this objective.

Posing Intriguing in-text Questions

— Analysing and extrapolating: For example, an in-textquestion in a UKOU plant physiology course asks the students to analyse how the structure of xylem vessels is ideally suited for their role in water transport, bearing in mind the kinds of forces involved in upward movement.

— Seeing a problem and seeking ways to solve it

Designing Self-assessment Questions

- Understanding the logic of the subject : For example, suggesting methods for separating macromolecules on the basis of size, charge and solubility (UKOU cell biology course).
- Conceptualisation of methods and practices to be followed : For example, giving self-assessment questions (SAQs) on scientific investigation about the efficacy of a drug against a certain disease bringing in various operations of scientific method (IGNOU Foundation Course in Science and Technology).

Providing Tasks

This is particularly useful where the learners are already in service.

- Identifying a problem and ways to solve it: For example, in the Zoo Animal Management programme run by the National Extension College (UK through open learning system) task-books are provided for this function.

Providing Work Sheets

- Recording and comprehension : This is particularly useful to widen perception or to give information in short steps, or to induce independent learning.

Giving Case Studies

- Actual insight into the practical problems and ways to solve them : For example, in a UKOU programme on Biotechnology there are 4 case studies which examine technological, commercial and political factors, which give actual insight into the practical problems by bringing in the real experience of different organisations using these concepts.

However, undue emphasis on print medium alone to inculcate the process of scientific inquiry may sometimes mislead students about the practice of scientific enquiry. The use of electronic media can make good this drawback. The sensory experience offered through the electronic media bring the student nearer to reality. Interactive video, computer simulations and games, teleconferencing (cyclops) etc., should help to provide real life situations in scientific observation and measuring, hypothesizing, predicting, analysing, inferring, extrapolating and evaluating. Though the use of these different teaching strategies brings the student very close to real experience, they cannot substitute it completely.

However, as many of the open university programmes are meant for people who are already in service, practical experience is easily available and can be provided easily. An excellent example of this is the course run by the National Extension College on Zoo Animal Management. The course material in this case consists of units, assignments, personal notebooks, self-assessment questions, activities, generalized topics, fact sheets, a project, and a task-book. While units and fact sheets mainly concentrate on transmission of knowledge, other components concentrate on comprehension, application of knowledge, data analysis, drawing inferences, development of practical skills required, formulating generalizations, evolving ways to solve a problem, testing and revising a theoretical model etc. However, this approach may suit only some programmes and in other programmes open universities may need to design separate practical courses. Since the laboratory contact and teaching sessions are minimal in the system (mostly through summer/winter schools and/or through home experiment kits), the student has to be prepared thoroughly to receive the laboratory sessions with ease and in the shortest possible time.

4. PREPARING FOR THE LABORATORY WORK

There are three broad aims of laboratory work (Black and Ogborn, 1979) :

Training Techniques : Techniques include manipulation such as the use of a particular equipment or experimental techniques, such as observation, measurement and adequate recognition of biological materials and mental techniques such as the analysis of errors or aspects of report writing.

Learning the Concepts peculiar to the Subject: Learning ideas requires an exposure to phenomena, the related concepts and the complexity of real situations.

Learning how to carry out experimental inquiries: Learning the process of experimental inquiry may involve project work in which students are responsible for the conduct of inquiry in an apprenticeship fahion.

These aims can be related to

* Development of technical skills
* Improving student's understanding of concepts
* Development of the process of scientific inquiry

4.1 Development of Technical Skills

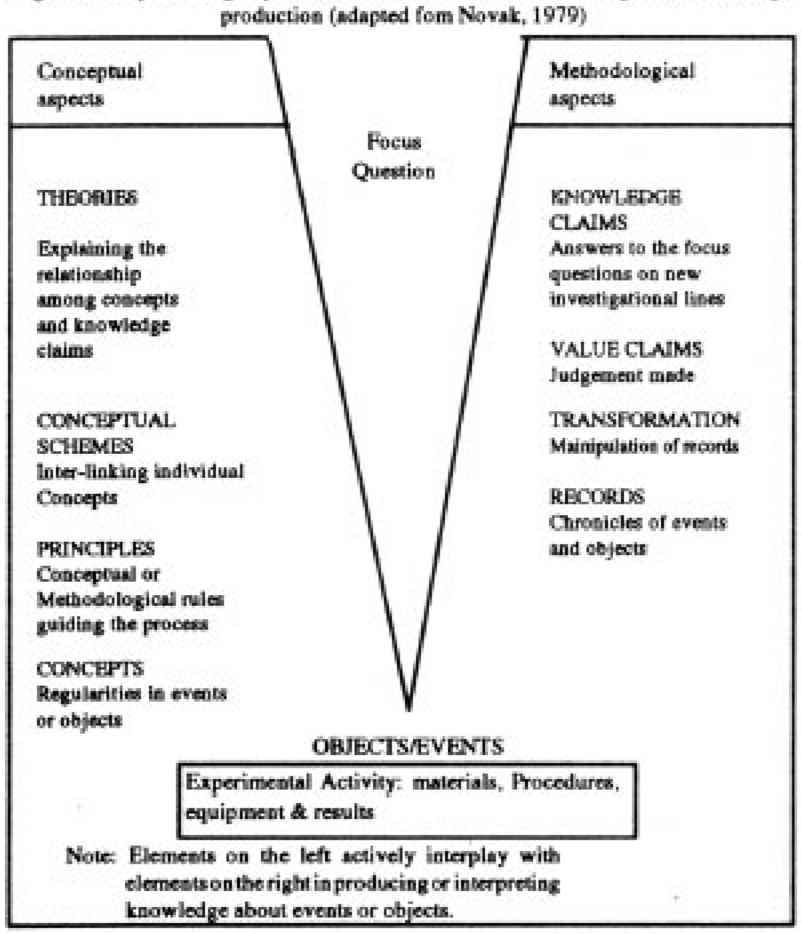
Although teaching of technical skills can best be done in a laboratory setting (Yager et al., 1969), different non-laboratory activities or methods have been shown to enhance the acquisition of technical skills. Video taped demonstrations as well as written instructions have proved to be effective in preparing chemistry undergraduates for their practical work (Kempa and Palmer, 1974; Gagen, 1978). Cavin and Legowski (1978) comparing computer simulated experimentation with laboratory practice in using a spectrophotometer, observed that computer simulation can be successfully used in teaching students the important procedural steps. Use of technique-kits for university chemistry students have been known to reduce faculty laboratory teaching load by atleast 50% (Runquist, 1979). Beasley's (1978, 79) studies on the effects of physical practice versus mental practice by university chemistry students on the skills required in volumetric analysis suggested the use of mental practice as an easy and straight forward aim to acquiring technical skills. He showed that mental practice is as effective as physical practice.

4.2 Improving Student's Understanding of Concepts

One of the criticisms of laboratory work is that the emphasis is usually on the methodological aspects of the exercise while the observations made or results obtained are not readily related in a meaningful way to the conceptual framework that underpins the experimental work. It is rather important to engage the students in some form of pre-laboratory activity highlighting the essential ideas basic to particular practical exercise, introducing new principles and concepts, and pointing out pitfalls. Different techniques are available for improving students' understanding of concepts and relating theoretical and methodological aspects of laboratory work.

One of the simplest ways of getting students involved in a practical exercise is to require them to answer a written assignment pertaining to the practical before they enter the laboratory. This helps the students understand the steps involved in the experiment and to identify the key aspects of the procedure. Another useful method for preparing the student for laboratory work is concept mapping (Cronin, 1984), a schematic device used to represent a set of concept meanings and the relationships that exist between them. Yet another important instructional device to link concepts and methods and to relate the observations and the results of an experiment to the conceptual framework is 'V' mapping (Novak et al., 1983; Novak & Gowin, 1984). At the base of the V (see fig 1) are the events or results that occur as an outcome of some experimental activity.

Fig. 1: 'V' map showing key elements in the Structue of Knowledge and Knowledge production (adapted fom Novak, 1979)



On the left hand side are the theoretical aspects of the work, increasing in generality from the bottom of the V. The right hand side is concerned with the methods used to generate knowledge, again arranged in hierarchical order — from records taken of the events to generalized knowledge claims. The major value of the V map is that it can be developed by students as an active consideration for all the facets of experimental science/activity, not just the methodological aspects but both methodology and deep understanding.

4.3 Development of the Process of Scientific Inquiry

Laboratory work can play an important role in aiding students' understanding of the processes of scientific inquiry and developing the intellectual and practical skills required at the appropriate level. Hegarty, (1982) based on David Ausubel's theory of cognitive psychology, Robert Gagne's theory of the learning of intellectual skills and Jean Piaget's theory of intellectual development, derives three major prescriptions for developing the faculty of scientific inquiry.

* Students cannot conduct meaningful inquiries in areas in which they have no background
* If students are to conceptualize the processes of scientific inquiry as conducted by scientists, there must be explicit teaching (about what scientists do and the nature of scientific inquiry, as well as implicit teaching that may be embedded in inquiry/discovery oriented laboratory exercises.
* If students are to experience the processes of scientific inquiry, course planners must design special learning activities. Laboratory 'cook books' are not effective.

Open university students may be prepared on these lines prior to or after the actual laboratory work in a number of ways particularly by using electronic media. The addition of special audio-visual materials to a laboratory teaching programme was shown to encourage creative thinking in the laboratory. (Hill, 1976; Tamir et al., 1982). Video tapes are shown to be effective in teaching students simple basic skills such as weighing and titration as well as advanced level techniques such as infrared spectroscopy (Pantaleo, 1975; Gagen, 1978). Computer assisted learning (CAL) can be used at a pre-laboratory stage very effectively to teach the process of scientific inquiry. It has already been used successfully as a pre-laboratory activity for different science subjects (Wilson, 1980; Moore et al., 1980). Wiegers and Smith (1980) reported reduction in time for completion of laboratory work by students who used CAL pre-laboratory lessons. Similarly, Gilbert et al., (1982) used computer programmes to optimize instrumental parameters in the use of spectrophotometer.

5. CONCLUSION

Using print and other media encompassing educational technologies and theories, it is possible to prepare learners effectively for developing scientific temper as well as for doing laboratory/field work in open/distance learning situations. As can be seen from the discussion, even using print as a major medium, different scientific attitudes and processes can be developed. This is an important recent development, as many of the open universities use print as their major medium for several reasons. Making the print medium interactive helps in reducing the time-honoured emphasis on frequent face-to-face sessions within the open university system. In teaching science courses in open universities, audio, video and computer technologies play a pivotal role not only to make amends for the infrequent communication between the teacher and the taught, but also to present and explain the processes which otherwise cannot be shown easily by a live teacher, and to simulate the real situations.

Preparing the learners for laboratory work using different media, including print, may be useful in two ways. On the one hand, it can reduce the contact time required for laboratory work and on the other hand, it may prove highly economical, reducing the laboratory cost. The open university approach is also highly useful in developing courses for in-service personnel. It may be concluded that science teaching in the open university system (or distance education system) can be as effective as in conventional universities and, in fact, is more useful for in-service personnel who are not in a position to spend their money and time to attend the conventional classroom based universities, and for those who do not get an opportunity to pursue higher science education otherwise.

Of course it is necessary to prepare science courses of different levels to suit different target groups ranging from laymen to scientists; from working personnel to managers in industries in order to build a new and successful culture of distance science education.

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