for the success of biodiversity research programme. Taxonomists alone, however, cannot tackle the diverse issues related to biodiversity. A collaborative effort by many kinds of biologists, including ecologists, geneticists, and physiologists is required and therefore training has to be multifaceted in order to develop a transdisciplinary approach for carrying out integrated biodiversity studies. One solution is to create centres groups specialized in inventorying and quantifying biodiversity at all levels. A greater interaction among survey organisations and such centres in universities is needed.

Initially the quantitative biodiversity research will be costly. Perhaps the Departments of Science and Technology, Environment and Forests, and Biotechnology can pool the resources to provide a joint umbrella for these studies. The Global Environment Facility may also be tapped for financial resources

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COMMENTARY

Foundation science and technology education

Amiya B. Sharma

In the middle of this century, the two science courses offered to students of arts at the high-school level were: (i) elementary physiology and hygiene and (ii) everyday science. Then the bifurcation into arts and science, and even further into 'pure' science and biology, used to take place just after the middle school, i.e. class VIII. The system was given up in the early eighties; now the students study history and geography along with physics and biology up to class X. At the plus-two stage (i.e. the higher secondary or advanced level) they begin to specialize in a few subjects – three, four or five: they can for instance, study geography and economics, politics and history along with a selection of science subjects.

The emphasis is now generally on familiarity with a broad range of fields rather than specialization in a narrow area. This has many advantages. The school prepares the student to correlate different areas of knowledge after one has specialized in a particular subject.

The philosophy of broad-base education has been accepted by the Indira Gandhi National Open University (IGNOU) even at the tertiary level. In contrast to many universities, where they do not teach any language to their science undergraduates and do not allow the arts students to pursue professionally their interest in science, IGNOU allows flexibility in the choice of subjects. However, out of the 96 credits* that a student has to accumulate in 3 years (minimum; maximum 8 years), 24 credits worth of courses are compulsory for *all* undergraduates – of science, arts and commerce. Of these there are two courses of 4 credits each in languages (English and a modern Indian language or an optional course in English), a course in science and technology, and another in humanities and social sciences, each of 8 credits.

Our BDP student may opt for courses up to 48 credits in a single subject and thus specialize in the chosen manner, if (s)he so desires. However, (s)he would still have to study at least one more course of 8 credits in another subject. For (s)he may study application-oriented courses of a maximum of 16 and a minimum of 8 credits. Against this background, we can say that IGNOU tries to ensure a broad base of knowledge, gradually narrowing down into a steeple. Alternatively, the student can choose to specialize by creating his/her own combination of subjects in consonance with his/her aim in life.

The idea of broad-base foundation courses in science & technology and humanities & social sciences may appear novel and revolutionary at the first instance. But learned persons all over the world have all along been emphasizing the importance of broad-base education, some of them being Samuel Johnson (1709–84)[1–2], Thomas Jefferson (1743–1826), Herber Spencer (1820–1903), A. N. Whitehead (1861–1947), and Abdus Salam. For example, Jefferson considered[3] geometry, trigonometry, astronomy, botany, chemistry, natural philosophy and anatomy worth the attention of every man and necessary for our character as well as comfort. His 'science' included[4] politics, commerce, history, ethics, law, arts and fine arts and was thus a synonym for knowledge. Although technology was never mentioned by Johnson and Jefferson, the former did seem to appreciate the relation between science and technology[5].

Spencer considered[6] science as the all-important knowledge for life: for self-preservation, which implies maintenance of law and health, and gaining a livelihood; for parental functions; for regulating the conduct of citizens, for the perfect production and highest enjoyment of art in all its forms; and for inculcating discipline – intellectual, moral and religious. Whitehead, perhaps more than anyone else before him, saw the intimate relationship between thought and manual skill, between science and technology. 'The peculiar merit', he wrote, 'of a scientific education should be that it bases thought upon first-hand observation, and the merit of a technical education is that it follows our deep natural instinct to translate thought into manual skill, and manual activity into thought[7].'

Salam[8] has opined that 'the science of today is the technology of tomorrow . . .'. He recorded how when he postulated a unification of two forces of nature – electromagnetism with the weak nuclear force of radioactivity – even *The Economist* took note and counselled perceptive businessmen not to ignore the likely economic consequences of this new development.

In the light of the idea of the unity of knowledge, the different segments of which are independently and profoundly developed, the two foundation courses taught at IGNOU – (i) in science and technology and (ii) in humanities and social sciences – seem to be a step towards accomplishing the aim of universal correlation or pantaxia, to use John Comenius's term, in concrete form. It is clear that the two courses should have several points of intersection as well as their independent areas of growth – one in many and many in one. The general aim in the two courses should be to instil in the student a curiosity in the various aspects of life. These courses should enable the students later on to pursue their special interests or diversify into different branches of knowledge. In what follows, we will limit our discussion to the foundation course in science and technology (FST). A block- and unit-wise breakup of this course and the supporting audio–video programmes are given in annexure 1.

The course was designed by a committee that finally approved of the main outline of the course and suggested names of probable course writers, out of which some finally wrote the units or the self-instructional lessons. The units which were in the form of essays were given the form of self-instructional material (SIM) by the in-house faculty at the school of science, more or less a standard practice. In some cases, the faculty has also worked on the topics and written the units.

The material, as the outline shows, is varied and rich and can make the student a scientifically and technologically conscious citizen. The range of subjects discussed is broad. One can learn about the astronomical revolution, evolution, the germ theory of diseases, superconductivity, the grand unification theory, relativity, ecology, environmental pollution, vitamins, diseases, psychology, behaviour, communication, the relationship between technology and economics, etc. The level of discussion is high, but appropriate for the student at the tertiary level. The discussions are frequently deep and at times even thought-provoking. The discussions, however, are not clear at a number of places. One factor which may not be very conducive to quality output is the absence of a clear indication of the individual contributors on the credit page.

One of the frequent sources of confusion is the absence of the relevant information, i.e. the concrete fact, at the right place. Let us take an instance from the SIM. In 31.2.1. We read.

> Once upon a time, 500 km was 'too far' (sic) and one could not contemplate such a journey, then perhaps 2000 km was too far, because the earth was thought to be flat and you could just drop off the edge . . .[9]

The impression that the lines convey is lacking in clarity. Similarly, in 1.2 we read about the tremendous advances in medicine and mathematics in India some 2500 and 2000 years ago[10]. Facts are not supplied immediately but later on. The discussions become clear only later. Ill-placedness and paucity of facts in support of contentions makes it necessary for the student to take *the teacher's* word for it. Due to the lack of focus, the common reader trying to discover the history of science and technology in the Indus valley civilization will find the discussions rather mixed up. A good SIM, on the other hand, should help the student form his/her opinion on the basis of examples and arguments. Per-

*An average student spends roughly 30 hours to earn a credit. During this period (s)he has to work through six units of about 5000 words each as well as do the exercises in those units. One is also expected to attend counselling sessions, listen to and watch the audio/video programmes in the given time.

haps if the course had been coordinated and edited by one person who would have had the aims clear, the course would have had a focus and been easy to follow and pleasant to go back to. As it is possible to tinker with the courses from year to year, we may hope that through deletions, alterations and fresh accretions the course would improve and become more useful in the years to come. However, notwithstanding its shortcomings, there are many insightful observations on the progress in science. For instance, in ref 11 the author authenticated the need for a link between science and technology as also that between language and learning.

The present course is given to the students in both English and Hindi. The course in Hindi, the language in which about 60% of our students take our courses, will help bring about generations of citizens who would be scientifically and technologically more aware. One of the expected outcomes of a successful course in science and technology would be that the student's common sense and reason would be sharpened and they would examine religious beliefs and question many of the precepts of religion, weakening the authority of religion as an institution. It is not undesirable that a unit be devoted to science and religion, where the student should be made aware of the different dimensions, such as personal and institutional, of the issue as well as the contradictory opinions about God.

It is reasonable to expect that foundation courses in science & technology and humanities & social sciences would whet the appetites of the students for this sort of broad-base science studies that they seek to promote. The university should have some higher-level courses which the students may be able to take if they wish to pursue further studies in that area.

One of such courses could be a diploma in history, philosophy and sociology of science. A brief outline of such a course is given in annexure II Here history of psychology and general physiology e.g. have been left out but there may be interesting courses in them. There can also be courses of shorter duration To make the courses interesting to the local students, e.g. in a course on superconductivity, we can allude to the work of the two Indian scientists – S. N. Ekbote and A. V. Narlikar – at the National Physical Laboratory in New Delhi. Such a strategy may entice the learner more easily.

If the diploma course is made with some imagination, it can take off. It would be a pioneering type of course in India. Different universities have made half-hearted attempts to make such a course. However, they had no success because no university can bring together the historians, philosophers and sociologists of science, few and spread as they are all over the country. The open university can bring together the experts as their physical presence is not needed at the university to make the courses suggested here.

In the second place we can have a course in science and literature. A brief outline of such a course is provided in annexure III. The outline exhibits a bias towards the literary impact of scientific thought. If there are experts willing to write lessons on the psychological aspects, we can have one more optional course in literature and psychology under the diploma course in science and literature[12–14].

For a subject to become a course of study at an educational institution, certain factors, not purely academic, have to be considered. For example, at IGNOU, each of these courses may be done in a minimum of one and a maximum of three years. There may be a provision that if a student completes both courses successfully then (s)he may have an MPhil in lieu of the two diplomas. We may hope that a group of scholars with such a general background will be able to take care of the two foundation courses better. They can also then look after and upgrade the quality of the two courses proposed here. If the open university prepares such courses, the conventional universities will be able to open new departments in these areas with the help of our print, audio and video material and our graduates. If science leads to enlightenment and an enlightened public opinion is the greatest protection against external and internal dangers, against the fraud of the misleading priest and politician, then courses in popular science and technology are the best bulwark against any threat to peace and prosperity. The significance of science is all embracing and we need people in all walks of life to be familiar with the methods of and discoveries in science.

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Annexure I

FST 1

Foundation Course in Science and Technology — *8 credits*

I. History of science

1. Science as a human behaviour
2. Science in the ancient world
3. Iron age
4. The golden age of science in India

II. Emergence of modern science

5. Science in the medieval times

6 Renaissance, the industrial revolution and after
7 Science in colonial and modern India
8 The method of science and the nature of scientific knowledge

III. Universe and life: The beginnings

9 Universe as a system
10 Exploring the universe
11 Solar system
12 Origin and evolution of life
13 Evolution of man

IV. Environment and resources

14 Ecosystem
15 Components of environment
16 The changing environment
17 Natural resources
18 Resource utilization, planning and management

V. Agriculture, nutrition and health

19 Food and agriculture
20 Scientific possibilities and social realities
21 Food and nutrition
22 Health and disease

VI. Information, knowledge, insight

23 Mind and body
24 Psychological aspects of behaviour
25 Information and communication
26 Modes of communication

VIII. Science, technology and development

27 Science and technology in industry
28 Technology and economic development
29 Modern developments in science and technology I
30 Modern developments in science and technology II

VIII. New perspectives

31 Perceptions and aspirations
32 Science – the road to development
Epilogue

Audio Programmes (in English and Hindi)

Science and Society, Astronomical Development in India, Measuring Astronomical Distances, Evolution of Man, The Forest Ecosystem, Population Pressure, Common Misconceptions about Health, Human Factors in Engineering, New World Information and Communication Order, Technology and Self-Reliance, Nuclear Disarmament

Video Programmes (in English and Hindi)

The Method of Science, Window to the Universe, The Story of a River, The Green Revolution, Infectious Diseases, Jean Piaget – Development Stages, INSAT

Annexure II

Diploma programme in History, Philosophy and Sociology of Science (proposed)

This programme should be of interest to a wide variety of post graduates intending to embark upon or in the early phase of their research or are academic career The minimum qualification is proposed to be 55% marks (minimum) at the master's level It should be expected that the participants would have interest in and a general knowledge of the concepts and ideas in science

The first two courses below in the history of science and a project are proposed to be mandatory From the remaining courses the students are allowed to select any two The minimum number of credits for the proposed diploma is 30

I	History of science and technology in the West	6 credits
II	History of science and technology in India and China	6 credits
III	History of Mathematics	6 credits
IV	History of Biology	6 credits
V	Philosophy of Science	6 credits
VI	Sociology of Science	6 credits
VII	Science Policy, Education and Public Understanding of Science	6 credits
VIII	Project – on a topic approved by the faculty	6 credits

This course can become still more useful, interesting and would be sought after if optional courses in history and philosophy of *history, education, linguistics, sociology*, etc , are also made available to the students

Annexure III

Diploma programme in Literature and Science (proposed)

It would be advisable for the student to undertake this programme after having completed the course in history, philosophy and sociology of science A background of literature may be also helpful.

The credits-worth of this programme may be 30. The participants may study any five of the following courses

I	Science and the popular essay	6 credits
II	Science fiction	6 credits
III	Utopia/Dystopia	6 credits
IV	Science in English Literature in Historical Perspective	6 credits
V	The texts of science and their context	6 credits
VI	Project – on a topic approved by the faculty.	6 credits

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