The science of the earth, and earth science education in India

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It takes earthquakes and tsunamis for the science of the earth to merit editorials in scientific journals. It took a tsunami to move the mind of the editor of *Current Science* – P. Balaram from the glamorous world of Physics and Albert Einstein to the 'extraordinary' affairs of the earth[1]. Natural disasters and hazards evoke awe and fear amongst the poor and the rich, the learned and the not so learned, and perhaps most life forms that dwell on this planet.

After the tsunami of 26 December 2004, media attention on the subject ensured that 'instant' experts sprang up from amongst the community of earth scientists. TV anchors and newspaper reporters chased earth scientists and some amongst them went scurrying to glean knowledge on the subject from textbooks on natural disasters, the Internet, and other sources. A brainstorming session on the subject has already been held at the Indian National Science Academy, New Delhi on 21–22 January 2005. Government departments have begun exploring the possibilities of establishing an early warning system for the Indian Ocean, perhaps, using the Pacific Tsunami Warning System (PTWS) as a model.

Balaram, in his editorial, quoted the Prime Minister's plea for a '*better understanding of the natural phenomena* (italics mine) that led to such disasters and of human activities that aggravated them'. This exhortation is of great import. Like many other high magnitude natural events, this one will find its place among the important historical records of disaster-related major natural events. One more set of statistics added to a table in a book that lists earthquake magnitudes, tsunami speeds, and the numbers of the dead and the missing.

That is where matters would have normally rested, but then the molecular biologist editor in his severe indictment has captured the state of geological education in India. 'Geology is a subject that is taught classically and traditionally in many places, *dull, descriptive and untouched by the excitement of modern science* (italics mine). These courses have few takers, students coming to the earth sciences only after many other options have been exhausted'. He goes on to add that the plight of earth sciences is rather poor in the Indian universities. Earth scientists in the academia have not looked at a 'mirror' for a long time.... beyond paying general lip service to the cause of improving geoscience education in India. From his position of an 'outsider' Balaram has suggested 'revitalization of some of our major earth science departments and also the starting of new and modern programs in some of our best institutions . . .'.

Will it take more than a 'tsunami'-sized disaster for academics to initiate some meaningful measures to improve the educational scenario in earth sciences in the country?

Realization that there may be much that is wrong with earth sciences education in India is an important first step. Acceptance of this fact (as far as I am concerned) in itself will lead to marginal improvements, at least by way of quick steps for revising and updating course content both at the undergraduate and post-graduate degree levels. One of the critical points of difference in earth sciences education in comparison with that of physics, chemistry and biology is that the student's first meaningful exposure to the geological sciences is at the undergraduate degree level. Barring Kerala, and perhaps a few other states, geological sciences/earth sciences as an option is not offered in the science stream at the +2 level. This is despite the much talked about *important place of environmental sciences in optimally 'negotiating' with the earth.* The NCERT, in its wisdom, has not thought it fit, thus far, to initiate the task of preparing an India-centric modern syllabus of earth sciences for our plus two students. Once that is in place, a task force could be set up to prepare a well thought out textbook and course materials. It would then be for the educational authorities of different states to assess the utility of this course material in 'shaping' the minds of those young citizens who dwell *the 'earth' of India.* This is a challenging task – a challenge of initiative from the NCERT, and a challenge for those who prepare the syllabus, for those who prepare the textbooks and course materials, for the state educational authorities, and for those +2 stage students who would be the pioneers or guinea pigs! This first step of introducing the geosciences option at the +2 level is *necessary* for raising the standard of geosciences education at the degree level.

New developments in the area of technology – satellite, information, and instrumentation (mass spectrometry, magnetism, microscopy, etc.) have had a profound impact on most sub-disciplines of the geosciences. The 'scales' at which data can be generated and the speed with which it can be integrated and modelled has led to revolutions in viewing the earth and its components from space, in recognizing and modelling the processes and rates of change of the many dynamic systems of the earth, and in imaging the earth's interior.

Are university earth sciences departments in India in a state of preparedness to appreciate the changes that have taken place globally? There is no single earth sciences department in the country whose course work is oriented towards understanding the earth, its oceans, and its atmosphere in an integrated manner, let alone consider the issues of coupling related to these systems. We continue to zealously guard our own domains of the solid earth, the oceans, and the atmosphere. This integration of 'thought' is a much farther goal than the integration of just geology and geophysics courses. This latter step took place almost three decades ago in most of the leading universities in the world, following the plate tectonics revolution of the sixties. We still continue, in our wisdom, to fight our turf wars between geology and geophysics.

Often, a view is expressed that geoscientists have not done well in India because of an inadequate knowledge of physics, chemistry, mathematics, and for that matter biology. Whilst this may be true to a certain extent, it must be emphasized that the 'sum' of geosciences is much more than it being just the physics, chemistry and biology of the earth; it is indeed the complex 'sum of the history' of the physics, chemistry and biology of the earth. This brings me to a quotation from Hans Cloos 'We decipher the earth's diary that has been left us a legacy. We read with trained senses and interpret with the tools of disciplined thinking. We translate the earth's language into our own, and enrich the already bright and colourful surface of the present with the knowledge of the inexhaustible abundance of the past'. Colleagues from the physical, chemical and biological sciences have a rather clouded and dim view of the geosciences – *dull, descriptive and untouched by the excitements of modern science*. Perhaps, a quotation from Victor R. Baker's[2] Presidential Address at the Annual Meeting of the Geological Society of America in 1998 may be of some help and relevance here to take away some of the cloudiness and dimness – 'Almost alone among modern sciences, Geology has preserved a **method of inquiry that emphasizes synthetic reasoning for the interpretation of earth's signified causal process.** Though geologists interpret earth's signs via all manner of *measurement, quantitative modelling, and experimentation, these are but tools for an inquiry ultimately directed at the truth of the earth's message* (italics mine). To interpret these signs, geologists do not need a foundational metaphysics to ground their reasoning . . .'. He further states 'If Geology is just physics, chemistry, mathematics, etc. applied to the earth, then its future will be a reduction to those more fundamental sciences . . . if geology has its own unique mode of reasoning, then cultivation of that mode of reasoning will be critical to advancing understanding of earth'. Yet another former GSA President Fairchild[3] stated 'Geologists have been far too generous in allowing other people to make their philosophy for them'. Baker has emphasized strongly that geology is 'a science of connection to our real environment, informed by the action of signs, a geosemiosis', and that '*geology's great intellectual strength* (italics mine) does not lie in some generic scientific method for testing purported truths'.

The Presidential Address by Baker has a single world title 'Geosemiosis'. Geologically important philosophy, according to Baker, 'involves a semiotic point of view wherein signs are not mere objects of thought or language, but rather are vital entities comprising a web of signification that is continuous from outcrops to reasoning about outcrops. Such an action of signs constitutes a geosemiosis that leads geological investigations on a fruitful course of hypothesis generation. While not being a method for doing geology, semiotics provides a means of describing the highly *productive reasoning processes of geologists* (italics mine)'. Earth science education at the undergraduate level will have to emphasize this philosophical strand if the student has to have a *meaningful engagement with the earth* as a whole or with any of its component systems.

One may well ask whether there are a few existing departments of geosciences in universities in India that can impart education at internationally competitive levels. The number may be small, but there are some; and these universities should get their act together and immediately begin the integration of geology and geophysics programs and departments. Also, we should take steps to seed new programs, that are amply 'touched' by the excitements of modern science, in some of our leading institutions such as IIT, Kanpur; University of Hyderabad, Hyderabad, the Indian Institute of Science, Bangalore, and perhaps the Northeastern Hill University, Shillong.

There is a strong need to emphasize the 'earth systems' approach in geoscience teaching and research; this would require an integration of knowledge of the atmosphere, lithosphere, hydrosphere, and biosphere. Such an integration cannot possibly be achieved in a typical three-year degree program which is currently offered by most colleges and universities. Instead, a four-year degree program in earth systems science should be offered to enable an integrated study of the earth, encompassing the evolution of the planet and its internal processes, and its surface processes; and also emphasizing the natural and anthropogenic factors that affect the earth's environment. To serve the future generations better, such a program should offer modular courses in the basic disciplines – mathematics, statistics, fluid mechanics, thermodynamics, ecology, computing, courses on earth systems (solid earth, oceans, atmosphere), earth materials (mineralogy and crystallography, sedimentology, petrology), earth processes (structural geology and tectonics, palaeobiology and biogeochemistry). Of course, instruction on relevant tools such as field mapping and survey methods, GPS and geodesy, remote sensing and GIS, microscopy, geochemical and geophysical exploration would also have to be imparted to the budding geoscientists.

In the past, geosciences have had a strong interface with engineering – mining, civil and hydrological, petroleum, and metallurgical. In the future, sustainable development of the planet will require well trained earth systems scientists who would be able to interface with earth systems engineers.

1. Balaram, P., *Curr. Sci.*, 2005, **88**, 5–6.
2. Baker, V. R., *Geol. Soc. Am. Bull.*, 1999, **111**, 633–645.
3. Fairchild, H. L., *Geol. Soc. Am. Bull.*, 1904, **15**, 248–266.

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