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CHAPTER 7 ANTICIPATED CHANGES IN EDUCATION AND TRAINING

7 (a) Earth Science Degree Changes; Curriculum Changes

In Canada, as in most countries of the developed world, both student enrollments and earth science curricula are changing rapidly. In part the changes reflect changing employment patterns, in part they reflect the advances that technological changes have brought to the field, and in part they reflect the growing public interest in, and concern for, the rapid changes that are happening to all parts of the environment. Evidence of the changes are not hard to find. Data published in *The Geosciences in Canada, 1993: Annual Report* (Canadian Geoscience Council, 1994)) report a steep decline, nearly 50%, in B.Sc. students graduating in the earth sciences over the period 1985 to 1990 (Fig. 7.1). The decline appears to have bottomed about 1990 and has risen slightly since then. At the same time, there has been a dramatic increase in the number of students registered in earth science service courses. Apparently most of the service courses that have benefited from this dramatic growth are in the environmental area. Enrollment patterns for graduate students have not shown this dramatic rise and fall through the 1980's and, in general, display a slow increase with time. Hiring in the Canadian petroleum exploration industry has shown an increase over the last three years (Fig. 7.2).

A similar trend to the growing interest by undergraduates in environmental courses can be discerned among graduate students. Most universities and colleges still offer a solid range of traditional earth-science courses. Increasingly, however, graduate programs related to environmental issues (groundwater purity, stream pollution, acid rain, *etc.*) have joined the curricula. Data for all of North America presented by Professor Marco Einaudi at the 1994 Annual meeting of the Geological Society of America show that approximately a half of all M.Sc. degrees in the earth sciences in 1993 were in what is now called environmental geology and hydrogeology (525 per year). Ten years ago the rate was only 20% of the total (289 per year). Ph.D. degrees show a similar drift toward environmental topics. Given their specialties, it is hardly surprising that more and more newly appointed faculty start teaching some aspect of environmental geology.

A second topic area that is growing rapidly is earth system science. This is largely a technology driven growth, but public interest in the topic is growing rapidly too. The Earth is viewed as a system of reservoirs (*e.g.*, the atmosphere, the ocean, the lithosphere) between which materials and energy move in endless cycles driven by the internal and external (solar) energy sources. Of particular interest is the possible influence of human activities on reservoirs and fluxes and hence on the cycles. The technological, space-age component is our growing ability to make continual measurements of the reservoir contents, as well as the fluxes, from remote satellite-borne platforms. For the first time we are coming closer to studying earth science processes in real time.

As a result of curriculum changes, the traditional balance between field observation, laboratory and theory is being changed toward model-based studies using aggregated data. The declining pool of skilled field observers, together with rising public concerns for the health and safety of the environment, has led to growing pressure for professional accreditation and/or professional registration.

7(b) Mechanisms to Facilitate Change

Changes to the academic system are influenced by education being a provincial responsibility and the provinces' concern is largely with the undergraduate programming. Funding for academic research is provided by federal NSERC grants and to a lesser extent by other government and industry grants and contracts. In many provinces there are annual meetings of chairs of geoscience departments and nationally there is an annual meeting of the Council of

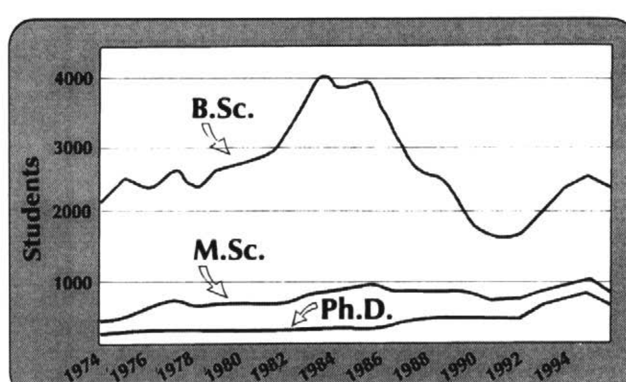

Figure 7.1 *Number of B.Sc., M.Sc. and Ph.D. registrants in Canadian university Earth Science Departments from 1973/47 to 1993/94 (CGC, 1994).*

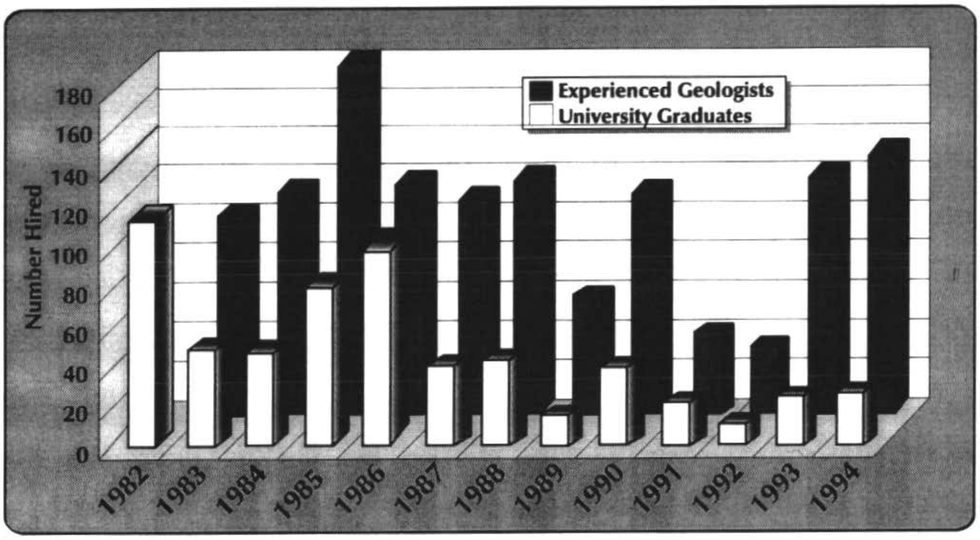

Figure 7.2 *Trends in the hiring of recent university graduates and experienced geologists from 1982 to 1994 (Deutsch, 1995).*

Chairs of Canadian Earth Sciences Departments (CCCESD). One continuing activity of the Council is to assemble enrollment and staffing statistics, provided to the GSC under contract and published as a summary in the CGC Annual Report. The CCCESD is, however, not yet an effective body and meets too infrequently to consider adequately many of the issues with which it should be concerned. It is a body that has the potential to be more proactive in partnerships to facilitate some of the changes advocated in this report. It has developed earlier position statements on topics such as NSERC research policies, Canadian participation in ODP, and curriculum accreditation proposals.

The CCCESD has the potential to interact with the Geological Survey of Canada, the Committee of Provincial Chief Geologists, and geoscience industry associations in order to develop more formal collaborative arrangements and to help coordinate future research programs. National geoscience would be served more effectively if the talents and resources of faculty and student researchers can be integrated, where appropriate, into government and industry research projects. This requires the academic sector being involved in planning meetings from an early stage. Such greater involvement would result in a wider range of field and laboratory training for students. Even with current downsizing, a transfer or donation of resources between sectors could be arranged through greater coordination.

An important aspect of education and training in the earth sciences is through research projects undertaken by senior undergraduate and graduate students. The value of students acquiring field/ship experience and of working in partnership with industry or government researchers is stated elsewhere in this report. There could be a greater commitment by the industry and government sectors to participate in the education of the next generation of earth scientists. The statistics on enrollment for graduate students are illustrated earlier in this chapter and a commentary on highly qualified personnel is given in the NSERC Allocation Report (Appendix I).

The duration of the educational cycle (to complete an undergraduate and/or a graduate program) is commonly out of phase with the recruitment needs of industry (and to a lesser extent of government). As an example, the petroleum industry is currently experiencing a shortage of geophysicists and is being forced to recruit from related disciplines or from abroad. Industry is also seeking additional breadth in background preparation (*e.g.*, in economics, computing, communication, and team-work skills). Consequently, some companies are taking more direct responsibility for re-training and for adding pertinent information or skills to their employees as immediately required. One mechanism is the Learning Organization Approach to adult education. The emphasis now is on just-in-time training, which is customized to the employee's needs and has immediate re-enforcement through exercises based on current company/employee problems. The latest academic research or scientific information pertaining to a technical problem is introduced by experts in workshops, seminars, and fieldtrips and is combined with all information stemming from the companies recent activities (*e.g.*, exploration successes and failures on a particular play) by those actually working on the problem. In the broadest sense, an educational opportunity is being used to develop a further action plan to continuously improve performance. The relationship between university programs and the needs of industry merits detailed consideration by both parties. Cooperative education programs meet part of the problem, but universities could re-structure their potential offerings to include tailored in-house courses for industry.

7 (c) New Skills

An integrated approach to earth science requires the training of a new generation of "earth system scientists" equipped with a new array of skills. The challenge, however will be to provide cross-disciplinary training without so diluting the process that the students produced by such a system cannot make productive contributions to the field. We can do this by creating an environment of integration – an educational and research environment where the focus is on system integration but staffed by individuals who are fully expert in their particular field. Students should be trained in an atmosphere where earth scientists of all disciplines work together on common problems and where the boundaries between the sub-disciplines are both physically and spiritually diffuse. Within this setting, however, the new generation of "earth system scientists" must have a sound grounding in the fundamental principles of the basic sciences along with exposure to courses that emphasize new growth areas in earth science (e.g., hydrology, engineering and environmental geology) as well as those that deal specifically with the inter-relationships and feedbacks of the system. To facilitate this interdisciplinary training, students of earth system science must also develop new skills that have not necessarily been part of traditional earth science education. Among these skills are:

Numeracy

Although basic numerical ability cannot be considered a "new" skill, its requirement in an earth science curriculum will be new to many programs. Mathematics is the universal tool that allows our evolving understanding of earth system processes to be transformed into testable hypotheses and predictive tools. Some subset of our students must be primary contributors to the development of the increasingly complex models that serve as the medium of cross-discipline integration and must have a level of numeracy commensurate with this task. As practitioners of earth system science, however, all of our students must be capable of critically assessing the value (or lack thereof) of these models and must therefore be numerate enough to understand their basic underpinnings.

Computing Skills

The extraordinary advances in computational capabilities and analytical tools that have taken place in the last few years have revolutionized the way we in which we collect, manipulate, and visualize the ever-growing database of earth system information. Indeed, it can be argued that the availability of these tools and techniques have altered the way in which we think about the Earth and that without them the study of the Earth as an integrated system would be virtually impossible. As with the discussion of numeracy, some subset of our students will be directly involved in the development of new computer tools and techniques which will be applied to earth system science problems; these students will need to have high-level software development skills and will need to be fully versed in the most functional computing languages and utilities of the time (*e.g.*, C++, X-Windows, Open GL, *etc.*). While this level of computer skills should certainly be encouraged (it provides for the greatest flexibility in designing responses to analytical needs), it need not be required of the majority of our students for the rapid advancement of high-level application programs has, in many cases, provided extremely sophisticated analytical capabilities without the need for a detailed knowledge of computer code generation. We must however, assure that our students are skilled and comfortable with a range of earth-science relevant computer applications. Included amongst these are:

Database management systems

As the technology with which we study the earth rapidly improves so does the volume and nature of the data that we collect. Vast digital databases of remotely sensed imagery (both on land and at sea), maps, environmental measurements, samples and analyses, currently exist and are growing each day. These databases represent the fundamental building blocks for our study of the earth system and provide earth scientists with the ability to explore complex statistical relationships amongst multidimensional data. In concert with database management skills, students of earth system science must also acquire the network access skills necessary to be able to explore, retrieve, and supply data to databases residing world-wide on the Internet. With the growing access of the global community to the Internet we are seeing the development of the concept of distributed databases. Through the use of the World Wide Web, datasets on a particular topic (*e.g.*, multibeam sonar datasets of ocean ridge crests) that reside on computers all around the world can be accessed with the stroke of a few keys from any computer on the Web. Our students must have the skills to take full advantage of this remarkable capability.

Geographic Information Systems

What separates the earth sciences from many other fields is our exploration of data in a geospatial reference frame. It is for this reason that, the map is one of the most fundamental and critical tools available to the earth scientist. In recent years computer applications have been developed that allow us to explore complex geospatial relationships in a highly organized and quantitative way. These Geographic Information Systems (GIS) have, in essence, automated the map-making process, and in doing so, have added much of the additional functionality of database systems, statistical packages, and graphic display. A typical GIS will allow for the input of vast amounts of multidimensional data in a series of layers, each tied through a common geospatial reference. Thus one can accumulate information on surface lithology, subsurface characteristics, vegetation patterns, demographics, ground water properties, *etc.*, all within a geospatial framework. These data can be combined or sorted in any manner desired and the complex inter-relationships of the data revealed in a series of easily producable digital maps. This is exactly the type of analysis that earth scientists have been doing for years, but now it can be done quickly and precisely, in a matter of minutes (even in real-time in the field). This is clearly a skill set that will be required of the new generation of earth system scientists.

Graphics and Visualization

Our interpretive skills are inextricably linked to our experiences, many of which are visual. Thus the ability to visualize data inter-relationships can often greatly facilitate our understanding of complex processes or phenomena. This is particularly true in the earth sciences where many of our insights have been based on observations and field relationships. In the last few years an array of sophisticated graphics and visualization applications have become available and fairly easy to use. These applications can take in a variety of data types and produce a number of standard and specialized output plots. Of particular interest to the earth system scientist is a new generation of visualization applications that permit interactive explorations of complex multiparameter datasets in a natural and intuitive manner. When applied to topographic or bathymetric data these tools allow for the interactive exploration (often in stereo – a "virtual environment") of geospatial data (*i.e.*, one can explore a 3-D ridge crest and see sediment type or biological patterns draped onto the surface). The power of these tools is only beginning to be explored; our students must have the skill to take advantage of their potential.

7 (d) Public Awareness of Geoscience

Public awareness of science has gained considerable profile over the last decade and can be predicted to become a stronger force in the future. Politicians have urged scientists to communicate their concerns to the public constituency. Scientists have found a knowledge-thirsty society as evidenced by the success of Canadian media shows such as Quirks and Quarks, The Nature of Things, and the new Discovery Channel. Elsewhere in this report we note the high popularity of provincial and federal museums and science centres (e.g., The Royal Tyrrell Museum of Paleontology), which have been effective agents of popularizing and communicating science. In Canada, the Calgary Science Hotline has been one of the most successful regional coordinating organizations, with much of its early success being the result of Calgary geoscientists, notably Ward Neale and Godfrey Nowlan (ISPG/GSC). The Geological Association of Canada (GAC) instituted a new medal in 1995 (the ERW Neale Medal) to recognize outstanding contributions to the public awareness of the geosciences. Another significant contribution was by Derek York (Physics, University of Toronto) who for several years prepared a series of articles on science for the Globe and Mail There are many other local examples of dedicated service and achievement in this activity, but nationally the earth science societies have been unable to develop a sustained program of public awareness. The Canadian Geoscience Council is now mounting an expanded effort. For many years it has offered a successful EdGeo program, aimed at educational workshops and field trips for teachers.

From the lines of evidence noted elsewhere (e.g., attendance at museums and science centres ; science television and radio shows; new science magazines), there is a strong latent thirst for knowledge, particularly of the earth sciences, in the public. The Committee regards the public awareness of earth science to be a high priority to address with a strong commitment by all sectors to provide increased funding and in-kind resources and to fully support those key individuals who demonstrate special talents and interest in this area. Again, the Canadian Geoscience Council should continue to play a major coordinating role, although many activities will inevitably be best developed at the local level. Renewed attempts should be made to develop a strong liaison with the Canadian Science Writers Association. Some programs will be better tackled working in partnership with broader public awareness of science activities such as those supported by the Royal Society of Canada and Industry Canada.

The academic sector together with the education committees of the Canadian Geoscience Council and its constituent societies need to adopt a more systematic approach to ensure that earth sciences is taught more widely at the elementary and high school level. A wider appreciation of the discipline and its role in society may be developed given that only a small fraction of post-secondary students take even a basic course in earth sciences.