Issues and Proposals for the Supply and Demand of Science Teachers*

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I. Introduction

Since early in the 1980's country after country has reviewed the structure of its established industries and/or of its emerging prospects for industrialization. Although these reviews have had the primary purpose of relating industrialization to the changing world economy, they have had, at least to some extent, to take account of the new worldwide concern for the health of local, national and the global environments.

Without exception, I think, these reviews have concluded that a greater emphasis needs to be placed on achieving more effective science and technology education. Unlike earlier periods, when there was concern about science education in relation to the supply of future scientists and technologists, the concerns of the 1980/90's are also about the scientific and technological literacy of the whole population.

The impact of technology on the working and leisure lives of everybody is now so all pervading that a better appreciation of science, and the relation between science and technology, are seen as imperatives for all students at school - the citizens of tomorrow's world with its promise of even more technology.

Likewise, environmental problems and their solutions depend very largely on the co-operation of the mass of citizens. Without a much more widespread appreciation of how human societies interact with the biosphere, and of the role of science and technology in damaging and repairing the environment, it is unlikely that enough citizens will begin to act in an ecologically

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*This article was presented at an international conference on Science Teachers Education at Seoul, Republic of Korea in March, 1995.

sustainable manner and to support the difficult legislative decisions that are essential to achieve this goal at the levels of the country as a whole, and of the community of countries, as was demanded at the UNCED summit conference in Rio de Janeiro in 1992.

If this need for more effective science and technology learning is so universally recognized, the case for a large increase in the number and quality of science teachers seems to be very strong. Strangely, in many countries the economic pressures today to contain the state's expenditure in public areas, like school education, health and social welfare, are so great that this obvious case for growth in science teachers is being replaced by a call for more effective teaching by the current numbers of teachers or by even a reduced number of teachers.

Whichever of these scenarios is winning, and there are examples of both expansion and containment across the world, the need for *better educated science teachers* is common.

II. Criteria for Improvement

If the science teachers for schools, as the 20th century ends and the 21st begins, are to be "better" than those of the past, what are some of the characteristics that are needed, if the criterion of "better" is to be achieved?

1. a broader and deeper understanding of science through some tertiary study of at least two, preferably three, of its major disciplines.
2. an appreciation of the applications of science in society, particularly in their own country.
3. the experience of carrying out open-ended scientific investigations of a problem area - as distinct from mere practice at a pre-structured laboratory exercise.
4. practice and familiarity with how scientific knowledge is communicated in the science community and practice at communicating it to non-scientific audiences.
5. an ability to become familiar with, and use the many new research findings that now exist about more effective pedagogies for teaching the content of science.
6. familiarity with, and confidence in the use of computers in

science education. This does not mean just their use as on-line data processing additions to scientific instruments, a common experience now in tertiary science in many countries.

Ministries of education and the tertiary institutions - universities and colleges - carry almost all the responsibility for the quality of science teachers, as well as all other sorts of teachers.

The in-service education of existing teachers is primarily the responsibility of the ministries, although this needs to be done in conjunction with those tertiary institutions whose staff have valuable insights and knowledge that these experienced teachers need to be exposed to. The pre-service education of new or prospective teachers is the responsibility of the tertiary institutions. Again, the co-operation of the ministry in the provision of good school experience is essential. Such experience can be provided, evidence shows, in rather unhelpful or in very helpful ways.

III. Review of Quality in Science Teacher Education

In 1988/89, I carried out a national review of the education of science teachers in all the state ministries in Australia and in the 52 tertiary institutions with teacher education programs. Some of the findings of that review have, I believe, significance beyond Australia, because science has such an international character. These findings were:

- Science departments in the better research universities want to contribute to science teacher preparation, but it is a lesser priority for them than producing scientists, and particularly developing the next generation of academic research scientists. Accordingly, they did not include as much of 2, 3, 4 and 6 above, in the undergraduate science courses that a future teacher might take, as did some polytechnic institutions.
- Institutions that were essentially teachers colleges were weak on 1, 2, 3, 4 and 6. They were variable on 5, depending very much on an individual staff member

who had made the effort to keep in touch with research in science education.

- The leading universities for science research were also the ones with the strongest groups in science education research. The latter were the sources where 5 and 6 and to a lesser extent 2 were most evident.
- The leading institutions for science education research were the most active in the professional development of science teachers, both through their masters and doctoral programs and in-service activities.

I will return to some implications of these findings later in the paper.

Now I wish to review some of the responses in several countries to the need for "better" science teachers.

IV. International Developments

A common aim in a number of countries is strengthening of the science content of a pre-service teacher's education. Thus, Australia, Norway, the USA, Israel and the Philippines have all moved recently to increase the amount of science an elementary teacher must study. In the USA, a number of prestigious universities, known as the Holmes Group, declared in the 1980s that students would not be able to graduate in education for science teaching in secondary school without a major sequence in the sciences.

Conflicting responses to the educational component of a science teacher's education have occurred. At one extreme, England has encouraged the employment of teachers with only a strong science degree, and has converted the university-based studies in education (the Post Graduate Certificate in Education) into a more apprentice-like training, with longer periods in schools with an experienced teacher.

Australia seems likely, on the other hand, to double the educational studies for science graduates, so that the students' experiences in practice teaching can be followed by more reflection on, and by further practice of, the new pedagogies that are available for science education.

The present economic-induced slackening of demand for teachers by the school system enables either of these responses to be possible.

In Sweden, a new development has been the introduction of educational studies called *Didaktiks*, in parallel with the future teachers' studies in physics, chemistry or in biology. *Didaktiks* is distinct from *Pedagogics* - the Swedish equivalent of what many countries call Methods of Teaching (physics, chemistry, math, etc.). *Didaktiks* takes the epistemological nature of the content of science much more seriously than Methods subjects have hitherto done. It draws on the history and philosophy of science, and increasingly on the findings of research in Science Education.

In the USA since the mid 1980s there has been a great deal of interest and research effort into what Shulman of Stanford University has called "pedagogical content knowledge." I believe what the Americans are seeking in these studies is very similar to the Swedish and German idea of Didaktik. It is for this reason that I, and two Monash colleagues, invited ten leading scholars from 8 countries to join with us and some local teachers in producing a book entitled The Content of Science: A Constructivist Approach to its Teaching that was published in 1994.

Accordingly, I believe the way forward is to strengthen and broaden the science learning of teachers, and to relate that learning much more explicitly, as it is acquired, gained, to how it is communicated. The Swedish innovation is trying to do this.

It is not uncommon to find what are called concurrent programs for science teacher education. These have parallel studies in a substantive subject, for example, one of the sciences, and in education. Unfortunately, these studies are, in general, quite inadequately inter-related. This is the opposite of what the Swedish example is attempting. A major and continuing reason for this lack of inter-relationship is the fact that many of the institutions with concurrent programs have only weak or non-existent research in science education. The education staff are in no position, in either science or in contemporary science education research, to contribute usefully.

V. Implications

I referred earlier to implications from the findings of my review in Australia. These can be put simply in terms of the criteria for "better" science teachers described earlier. The most likely prospect for achieving these characteristics is for science educators, engaged in research in that field, to offer studies that draw on that research, and on the nature of science and its applications as technology, and to relate these studies closely to the science studies of the students. This requires (1) strong departments of science and of science education research in the same institution that are sympathetic to each other's contribution and (2) undergraduate programs that will allow these parallel interacting courses of study.

Such programs will be of benefit to the science students, whether or not they go on to be scientists or continue the educational studies and practice to become school science teachers. One justification for this claim lies in the high priority that industry now gives to communication skills, alongside investigative skills and co-operative working. My final remarks on the Demand side of the science teacher problem add to this justification.

VI. Demand for Good Communicating Science Graduates

It is inadequate to talk only of the Supply side of any field of professional expertise. Attention must also be given to the Demand side of the equation. However, because my background is essentially on the Supply side of science teachers my comments on the Demand side are less extensive, but they are, I suggest, quite pertinent.

Fifteen years ago, as the need for Science for All loomed on the horizon, I tried to persuade the Ministry of Education to develop a co-operative arrangement which would allow some school science teachers each year to have some experience in their vacations of how Science is practised in Australian industry. The reply by the ministry was that this was not a good idea because a number of these teachers might be attracted by the conditions and salaries in industry and so would be lost from teaching.

Five years ago, after one of the more broadly based economic reviews to which I referred at the beginning of this paper, a pilot project put 100 teachers into industry for one year, during which they were also to contribute ideas for curriculum development in order to get a postgraduate diploma. One third of these teachers took up jobs in the industrial companies and this is now seen as a valuable contribution to Australian industry's need for better communications. The pilot project has now been extended nationally.

Four years ago, the Engineering Faculty of my university gave the Education Faculty a contract to enable final year engineering students to take an elective subject that places them in a primary or secondary school with a teacher of technology. They contribute technical knowledge to the teacher, and in return, the teacher helps them learn to communicate to teachers, young students, and their parents. This scheme is seen as an important contribution to these future engineers since engineers are generally regarded as poor communicators to the general public - an essential skill for many engineers.

These two examples highlight, I believe, that there is a demand in society for graduates in science and technology who have learnt, in parallel with their scientific and technical studies, the skills that science educators now have. Some of these graduates will become teachers in schools and they will be our best hope to achieve the Science for All that so many countries now want.