and so on. These plants commonly leaked ammonia, thus presenting a significant occupational health hazard.

Ice boxes, used for domestic cooling purposes before the development of modern refrigerators, had cakes of ice placed in the upper section. The warm air rose, got cooled by the ice, and this cooler air then flowed downwards to the food compartments where it absorbed heat energy from the food (cooling the food), warmed up, and again rose towards the ice. This cycle continued.

The Changing Nature of Science Teacher Education: An Interview With Keith Lucas

Keith Lucas is an Associate Professor in the School of Mathematics, Science and Technology Education at Queensland University of Technology (Locked Bag 2, Red Hill 4059 Australia). His research interests include the construction of science meaning by students, science learning in informal settings such as interactive science centres, and the professional development of teachers and teacher educators, particularly in developing countries. Regular teaching involvement in recent years has included science curriculum for pre-service and graduate students, the design and teaching of Faculty based research methods courses, and supervision of candidates at masters and doctoral levels. He has served as editor of the *Australian Science Teachers' Journal*, Assistant Editor of *Research in Science Education* (the journal of the Australasian Science Education Research Association), a member of the Editorial Board and the International Committee of the National Association for Research in Science Teaching, and as a regular manuscript reviewer for the *Journal of Research in Science Teaching* and *School Science and Mathematics*. In 1991 and again in 2000, he was awarded the Australian Science Teachers Association Distinguished Service Award.

SER*: *Keith, you have been involved in teacher education for over 35 years. What changes have you seen during this time in the ways pre-service teachers are prepared?

***Keith*:** The most obvious change I suppose has been the length of the pre-service course taken by most science teachers. Forty years ago in Australia, a significant proportion of science teachers completed a basic three-year degree in science followed by a one-year diploma in education. Additionally, there were many who chose to attend the teachers' colleges, which were part of the state departments of education, rather than a university and to complete a two-year diploma of teaching course. These were the main entry pathways to a science teaching career although there were some others, notably some private schools employed science graduates without any professional teaching qualification such as a diploma in education. That was how my career as a science educator commenced.

In the intervening years, the two-year diploma courses lengthened, first to three-year diploma courses, then three-year and ultimately to four-year bachelor of education degree courses. The first two years of such courses are predominantly science based and the others predominantly professional studies in education, including science curriculum and practice teaching. The traditional bachelor of science degree remains a three-year course in most Australian universities, but science graduates are increasingly being required to complete a two-year graduate bachelor of education or master of teaching degree before being eligible for registration as a teacher.

So, there has been a significant increase in the duration of pre-service science teacher courses. Another change which I regard as very significant, and detrimental, has been the reduction in the quantity and diversity of science discipline studies required of pre-service science teachers. For example, the traditional bachelor of science course required students to complete at least one full year of study in four distinct branches of science, including mathematics. Today in many Australian universities it appears to be possible to graduate with a degree in one branch of science without any study in one or more of the other major branches of science. While graduates of such courses may be well suited for numerous occupations, science teaching at the junior secondary school level is certainly not one of them.

A related issue is the remarkable changes that have occurred in the number and character of the institutions in Australia that offer pre-service courses for science teachers. Teachers' colleges became colleges of advanced education (CAE) during the seventies, largely independent of the state education departments and increasingly providers of courses in fields other than teacher education. The CAEs generally did not offer post graduate degree course or conduct extensive research but were effective and efficient providers of quality teacher education, due in no small part to the demonstrated expertise and substantial in-classroom teaching experience of the teaching staff. A wave of institutional restructuring that included forced amalgamations of universities and CAEs during the eighties and early nineties, driven by economic rationalism and political centralist policies of the federal government, resulted in the demise of the CAEs. Priorities within teacher education institutions have changed in recent years: lecturers see their careers being advanced more by the award of research grants than by a commitment to promoting excellent teaching; practice teaching increasingly is problematic in respect of cost and availability of suitable placements for students; and the role of the specialist curriculum lecturer is being usurped by so-called generic approaches to curriculum and the proliferation of courses to meet particular political or social agendas.

Have you discerned any changes in the attitudes of pre-service teachers during the years?

This is a difficult question to answer, not the least because any changes I describe may reflect changes in me rather than changes in pre-service teachers! Nevertheless, I believe that the appeal of science teaching as a career option has decreased in recent times in line with a marked decline in the perceived social status of teaching within the community and higher financial rewards elsewhere.

Scholarships for pre-service teachers are now rare in Australia, but twenty years ago they were common, providing tuition and living expenses, and guaranteed employment on completion of the course. Typically scholarship holders were bonded to the state departments of education to teach for several years, often in small schools in rural communities. Acceptance of this condition constituted evidence of a high level of commitment to teaching as a career which is not always evident in contemporary pre-service teachers, especially if they were denied entry to more favoured university faculties such as medicine, engineering, or law. If entry to a pre-service teacher education is perceived by students as a consolation prize, their commitment to a long term career in teaching is not assured. However, it seems to me that in recent years there have been more mature aged entrants to pre-service science teaching courses–engineers and scientists with years of professional practice undertaking a career change. To do so usually requires of them a remarkably high level of commitment to teaching. In my experience, they transform the nature of the typical pre-service science curriculum class and enrich the quality of science education in school classrooms by virtue of their maturity and relevant life experiences.

One thing that puzzles me a little is that, while integrated science courses were introduced into Australian secondary schools well in advance of many similar countries, there appears to be a decreasing proportion of beginning science teachers who envisage themselves as teachers of science as distinct from teachers of a particular science. I suspect that an explanation may be found in the increasingly narrow and specialised nature of first degrees in science in Australian universities, combined with the demise of integrated discipline and curriculum programs characteristic of the teachers' colleges prior to the mid-seventies and CAEs to the early nineties. If I am correct in this, then there is an urgent need for science teacher educators to find ways to attract and retain young teachers who are keen and well prepared to teach broadly based contemporary science curricula across the compulsory years of schooling.

Do you have any suggestions for facilitating the professional development of practicing teachers?

I think that the best professional development programs for science teachers that I have encountered were conceptualised and facilitated by science teachers' associations at state and national levels, i.e., by science teachers themselves, and funded by generous grants from state and national governments. They were excellent because they did not adopt the common "deficit model" of professional development whereby teachers are perceived by others to be lacking in some important knowledge or skill, and these others set out to provide it for them. Unfortunately the provision of funds for in-service professional development programs to non-profit organisations such as science teachers' associations has been severely curtailed in recent years. You will gather from this that I favour professional development programs that are long term, teacher initiated and school based, and designed to address professional development needs that are vital to teachers themselves. Certainly they may involve "outsiders" such as curriculum developers or university based colleagues, but the impetus and control ought to rest with the teachers themselves. I think such programs have the best chance to make a difference to the quality of the science education of kids, which is really the only reason I can think of for supporting professional development for teachers.

In my view, professional development is a personal professional issue and the key is intrinsic motivation to improve one's own professional practice. Individual science teachers who recognise a personal need to enhance their professional competence are now better served than ever through the increased numbers and varieties of tertiary institutions and courses available. Before 1980 there were very few tertiary institutions in Australia offering post graduate courses suitable for science teachers intent on enhancing their classroom practice, and even fewer opportunities to complete them part-time in one or more of the flexible study modes that are now so familiar a part of Australian universities. Teachers can choose from post graduate diploma courses designed to introduce them to new knowledge and skills, masters degree courses in various areas of specialisation, and research degrees at masters and doctoral level.

What impediments do you see here?

Simply cost and time, from the teachers' perspective. Although places in research degree programs at doctoral level generally attract fee subsidies, and even meagre scholarships, these are in my view the least useful professional development avenues for young science teachers. Of course, the financial support offered for such research degree candidates has much more to do with the research profile and federal funding of the universities and supervising staff than the enhancement of the quality of the science education of children in school classrooms. For other degrees and diplomas,

teachers are required to pay substantial fees and to squeeze time for classes, reading and assignments into schedules already crammed with the multitudinous responsibilities of teacher, family and community interests.

Please don't misunderstand me here. I have worked with many teachers of science and other disciplines at diploma, masters and doctoral levels who have accepted the costs involved as a normal part of their personal responsibility for their own professional development and somehow have found the time to engage in the courses enthusiastically. They value the outcomes highly in terms of their own professional development. There are many excellent opportunities for professional development through courses designed for, or suitable for practising teachers in Australian universities. My concern is simply that many many more teachers do not avail themselves of these opportunities. I understand that cost and time are major impediments to them doing so.

Any thoughts about ways of better sharing the wisdom of experienced classroom teachers?

I presume that you mean by this, sharing among colleagues who are classroom teachers of science. This is a challenging issue. As you know, the state and territory science teachers' associations in Australia, and the national science teachers' association which is an affiliation of the state and territory associations, have been active for more than 50 years. Membership has waxed and waned over the years, never achieving membership levels inclusive of the majority of science teachers. However, the associations at state and national levels continue to provide wonderful opportunities for the kind of sharing that you refer to. Nevertheless, we live in a changing world, and strategies such as annual conferences and print journals that have served the associations well in the past are being found lacking in meeting the requirements of contemporary teachers. Strategies are needed for revitalising the associations and capitalising on new technologies to establish communities of professional practice.

I am a fan of schemes that enable teachers to visit and work a while in different locations. A few such schemes have operated over the years to enable Australian science teachers to exchange teaching assignments with colleagues from other states or other countries. An example was the UK/Australia Fellowship for Teachers of Science which provided for ten Australian teachers to exchange with UK colleagues between 1990 and 1995. Sadly sponsorship lapsed. In my view, increasing the availability of opportunities for science teachers to travel and work overseas would be an excellent way to share the wisdom of experienced teachers of science among their colleagues, and at the same time to invigorate the professional practice of the travelling teacher, because sharing is a two-way activity.

Occasionally during my career in teacher education we have been able to find funds to enable us to appoint "visiting teachers" to our department for one or two semesters. Their role was not to teach, but to interact with the regular faculty, thus, to use your phrase "sharing their wisdom of experience" with staff and students. We found this to be an extraordinarily beneficial venture for all concerned. Visiting teacher programs should not be confused with an emerging practice in Australian universities of "using" secondary science teachers, and graduate students, as low cost part-time staff to teach undergraduate curriculum courses to pre-service teachers.

What has not changed during the years?

Several things appear not to have changed very much during the past four decades. There is still a serious shortage of well qualified science and mathematics teachers in primary and secondary schools, especially in senior physics and chemistry. Also, I've not noticed much change in the overwhelmingly large proportion of science teacher education students and practicing science teachers who are dedicated to their students and to the promotion of high quality science education in Australian schools. Despite the changing nature of teachers' work, dedicated teachers seem to thrive on the challenge and professional satisfaction associated with teaching science at all levels of the school. Finally and disappointingly from my perspective, there has been little long term change in the low proportion of science teachers who are active members of their state and national science teachers' associations. I have derived much pleasure and a tremendous amount of professional help and direction from my involvement with the state and national science teachers' associations since my early years as a secondary science and mathematics teacher in Sydney. I'd like to think that that will continue for me, and an increasingly large number of my science teaching colleagues well into the twenty first century.

Thankyou, Keith.

Further Useful Resources

Volvo Ocean Adventure http://www.volvooceanadventure.org

An environmental education learning experience using data collected by yachts in the Volvo Ocean Race, a round-the-world yacht race. Sensors monitor plankton levels in the oceans, and satellite imagery from NASA and ESA [European Space Agency] is used. Data will also be available for classroom use after the race finishes. The data may be used by students to develop an understanding of the workings of the oceans and the impacts they make on our climate and food chain, to perform