Teaching about Science Teaching and Learning:

research should inform practice

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Introduction

School science has long been characterised as teaching that is factually based and learning that is 'appropriate' for passing school science tests but has little impact on students' understanding of everyday evvents. It is therefore important to better understand what research can tell us about the nature of science teaching and learning in schools and to use this knowledge to shape all levels of education (elementary, secondary, tertiary - teacher education in particular).

The following paper therefore considers some of the pertinent Australian research in science teaching and learning and links these ideas to our hopes and expectations and practice in education. Hopefully, by so doing, the reader might find ways of taking some of these research findings and applying them in their own science teaching in order to enhance students' science learning.

Background

It has been well documented in the Australian research literature that the perceived lack of science content knowledge of elementary teachers creates difficulties in both their teaching of, and attitude toward, science. For example, Appleton (1981; 1983; 1991; 1992) and Skamp (1987; 1989; 1991; 1992) in particular have conducted numerous and extensive studies exploring the relationship between elementary teachers' science content knowledge, skills and abilities in teaching science, their attitudes toward science teaching and learning, and interestingly, how the age and experience of student-teachers influences each of these (mature age students compared to 18 year olds directly entering teacher education from High School).

Jeans and Farnsworth (1992) conducted surveys whereby 1,000 questionnaires were mailed to 281 elementary schools. Their survey examined the strength of teachers' opinions about teaching science.

> There was a general feeling that science education has a long way to go before it could stand alongside language and mathematics in matters of time and resources allocated, teacher knowledge, confidence and enthusiasm, and in matters of quality. Many thought that science was inherently exciting for teachers and pupils and that what they, personally, were doing was inadequate... it is also clear that very few individual teachers have the knowledge-base needed to construct an interesting, developmental science education program. (Jeans and Farnsworth, 1992, p. 221)

Appleton and Symington (1996) reviewed the development of elementary science teaching from the mid 1980's to the mid 1990's. They demonstrated that concerns related to these issues (above) were slowly being addressed in teacher education programs. This was partly due to the fact that the professional development initiatives designed to help practising elementary teachers better teach science took time to similarly influence the manner in which science teacher education for elementary teachers was being conducted. However, there have been important gains as programs such as PECSTEP (Primary and Early Childhood Science Teacher Education; Bearlin, 1990), LISP (Learning in Science Project; Bell, 1993) and Sci-Tech (Science and Technology in-service program; Napper and Crawford, 1990; Crawford and Zeegers, 1993) have become influential in helping Elementary Science Teacher Educators reconsider and reshape their curriculum and teaching. In fact, in many cases these programs were organised and conducted by elementary science teacher educators themselves intent on addressing the concerns related to science teaching in elementary schools. This is an important issue then for science education. Changes in teaching and learning in schools needs to be both fostered and supported by science teacher educators.

On the other hand, many prospective High School Science teachers enter their teacher education programs with somewhat different concerns to their elementary counterparts. For example, many pre-service science teacher educators have long felt that the approach to teaching science in under-graduate studies (Bachelor of Science) was not conducive to helping these candidates form appropriate views of science teaching and learning as they were the 'survivors', or most able absorbers, of science knowledge through what is largely regarded as a transmissive approach to science teaching.

Bucat and Williams (1989) particularly highlighted the problematic nature of the undergraduate approach to teaching science when they studied student note-taking in Chemistry lectures. In quite an eloquent study they worked with four Chemistry lecturers and 160 students across 80 lectures (of 45 minutes duration), as they attempted to examine the relationship between what the lecturers themselves considered to be the important information units being portrayed, and those which the students actually noted themselves. The reliance on chalkboard signals was significant, as was the quantity of information transmitted.

> The number of pieces of information which students needed to process to make sense of the lecture was surprisingly high. In the case of lecturer C, these ideas were delivered at an average rate of one every 11 seconds. Lecturer C has a rapid delivery style, but even the more typical lecturers A and B developed separate ideas every 16 and 22 seconds respectively... Contrary to the beliefs of many lecturers, not all students record all that is written on the blackboard [chalkboard] (although all students did record at least half of the blackboard signals)... The number of student records originating from verbal signals other than those that re-stated blackboard signals was negligible... it seems that if the lecturer considers it important for students to record information, then it is insufficient to discuss this

knowledge without the support of blackboard signals. (Bucat and Williams, 1989, pp. 42 - 43).

It is therefore not surprising that science teacher educators are often concerned about the views of science teaching and learning that their student-teachers 'arrive with' and are similarly concerned about how these views will influence their approach to learning to teach science.

One simple overview of the elementary and high school science teacher education dilemmas then is that elementary science teacher education concentrates more on processes of teaching and learning and does not adequately address the need for appropriate content knowledge, whilst high school science teacher education suffers from an overabundance of content knowledge to the detriment of understanding teaching and learning. One way of considering these differences is to place this knowledge in a context whereby students' learning of science needs to be better understood, hence the development of our understanding of 'alternative conceptions' or 'children's science' should be important in shaping the way we teach about science.

Children's Science

Throughout the 1980's there was an ever growing research literature that explored the way in which school students developed an understanding (or misunderstanding) of science. Gunstone and White (1980; 1981), Tasker (1981), Osborne and Freyburg (1985), Champagne et al, (1985), Treagust (1986) and Gunstone (1990) and many others, highlighted the importance of knowing about, and responding to, students' conceptions of science in school science teaching and learning. Fortunately, much of this development in understanding about how students interpreted their science learning influenced science teacher education but sadly, to a lesser extent, science teaching in schools.

Science teacher education programs began to use this research in curriculum formulation (as illustrated by Carr and Symington, 1991). Importantly, this research also created a need to reconceptualise and better link students' learning of science with the teaching of prospective science teachers. Therefore, in many ways it can be argued that a confluence of events, research interests, and educational changes toward the end of the 1980's combined to create the approaches to Science Teacher Education that exist in Australia today. However, it is important that an understanding of this research should similarly influence school science teaching and learning. If students' misconceptions about science are not appropriately challenged so that their understanding of the concepts is enhanced, then in a real sense, the teaching that they experience has little impact on their science understanding and therefore only reinforces the stereotypes (outlined earlier) that characterises much of the community's impressions of science teaching and learning.

It is therefore important that in schools the level of engagement in science learning that students' experience needs to be better understood by teachers and researchers if some of these changes in understanding are to occur.

Learning Science: the importance of challenge

Through the Teaching and Learning in School Science (TLSS, Baird et al., 1989) project, Baird and Penna (1996) explored the notion of 'challenge' in great detail and concluded that:

> The findings demonstrate that much of science learning and teaching fails to challenge students and teachers as it might. The causes for limited extent of challenge are multiple, and dependent on particulars of various pedagogical, curricular, personal and interpersonal, and contextual factors that are operating in a given classroom... Notwithstanding this complexity, however, the notion of challenge and of specific factors that influence it does suggest a way of acting to improve the quality of classroom practices. (P. 268)

Increasing the 'challenge' in science teaching and learning is important. Examples of this are evidenced in studies by Hand and Peterson (1995) who developed, trialed and evaluated a constructivist learning approach in their pre-service science teacher education programs in order to enhance their student-teachers' confidence and attitudes toward science teaching. Also, Peterson and Treagust (1995) attempted to develop their student-teachers' pedagogical reasoning and were successful as demonstrated by one of the student-teachers, Jane, such that, "the process that I went through, I believe was beneficial in developing my understanding of both the concepts being taught and learnt as well as the experience of actually teaching the concepts. This side was useful and made me aware of the needs for clear explanations, demonstrations, activities etc. in science lessons (Jane, Journal - 1/21)" (p. 304). Clearly then, if understanding challenge, and teaching in ways that enhance the sense of challenge can be developed in science teacher education programs, the same must be possible in schools.

This can be demonstrated on a larger scale by the work of Hoban (1997). He extensively studied his eighty-five pre-service elementary science teachers throughout his thirteen week science methods course. He aimed to help his student-teachers develop a self-awareness about how they did (or did not) learn science, and to consider how this impacted on the way they taught science.

Through his weekly practical classes (laboratory, hands on sessions) he challenged his student-teachers' knowledge and approach to science teaching and learning and collected data through student journals and interviews. He concluded that:

> Teachers have been labelled as 'transmissive' when they attempt to deliver facts to students as passive learners... Yet how different is it when teacher educators attempt to deliver educational theory to trainee teachers as passive learners in teacher education courses?... The challenge for teacher educators, I believe, is to bring theory to life and engage pre-service teachers as reflective thinkers in the knowledge-generating process... The written reports showed that 95 per cent (81/85) of the pre-service teachers believed that they developed a self-awareness about their learning and 93 per cent (79/85) commented on how this self analysis informed their views about teaching elementary science... the pre-service teachers described twenty-two ways that helped them to learn in my course. These included four individual influences (prior knowledge, personal motivation, personal feelings, and personal confidence) and eight social influences - four from myself as the instructor (teacher explanations, modelling of instructional techniques, relationship with the teacher, and teacher enthusiasm) and four from other students (group work, class discussions, type of activities, watching other students)...[for the teacher educator] you are getting a weekly evaluation of not only what you are teaching but also how you are teaching. Hoban, 1997; pp. 145 - 147)

This growing body of knowledge about science teaching and learning has been informing the way in which science teacher educators in Australia consider their roles as teachers, researchers and learners in their respective teacher education programs. Hence, another important aspect of this work is related to how student-teachers respond to the opportunities to 'experiment' with their science teaching in the real world setting of the school as they are clearly the next generation of science teachers and their practice is important to understand if science teaching and learning is to be enhanced. It is also crucial in the influence that these beginning teachers might have both with their students when they become teachers and their colleagues with whom they will teach in schools. Clearly then, the relationship between student-teachers/beginning teachers and their colleagues is important in influencing the nature of change in science teaching and learning in schools. This perhaps begins in the practicum experiences during student-teaching.

School Practicum

Like any teacher, science teacher educators are interested to see how their students' learning progresses over time. Hence, teacher educators are interested in exploring how the teaching and learning opportunities created at the University influence student-teachers' teaching in the school setting. The school practicum is one opportunity for this. However, the practicum arrangements vary with the differences in course format. Generally, in the Dip. Ed. Programs (one-year graduate program), there are three teaching practica evenly spread throughout the year, usually of approximately 3 - 4 weeks duration. In the Double Degree and Elementary programs, some school experience occurs in the early years of the course but the majority of teaching experience occurs in the final year (approximately equivalent to the Dip. Ed.).

The relationship between the University and the school is important and in many ways influences what student-teachers are 'allowed' to do during their teaching practicum as much depends on the school supervisor.

The complexities of the relationships between schools and universities has led to the notion of partnerships such that some universities have created particular arrangements with their schools. One example of this is described by Smedley and Van Rooy (1996) and they pay particular attention to the value of building the relationship between the university teacher educators and the school supervising teachers. Clearly, the better the relationship, the more likely it is that student-teachers will have the opportunity to 'experiment' with their science teaching in classes rather than simply be directed, or controlled, by their supervising teacher.

> Mutual respect develops as the teacher and the lecturer shape a partnership model with which they are comfortable. The form, content and tone of their discussion vary according to the contexts. The curriculum lecturer knows the student teacher well from tertiary sessions. The master teacher knows the student well from the weekly visits. The exchange of perceptions of the student-teacher's progress and advice which each can share with the other form the framework for the continuing education of the pre-service student both in school and at the university...As a result of the close and continuing working relationships established during the visits and meetings, the science teacher educators have developed a firm understanding and respect for the different roles and responsibilities within the partnerships. (Smedley and Van Rooy, 1996; p. 82)

However, not all universities have such responsive partnerships. In fact in the majority of cases, beyond working with a particular school (or set of schools), the university has little 'control' over who will supervise the student-teacher and therefore many other issues arise. For example, Berry (1995) examined the pedagogical development of student-teachers through their one year Dip. Ed. and one element of her research explored in detail the student-teachers' perspective on their school practicum experiences.

In some instances, the student-teachers felt as though the opportunities that they were offered in schools were too restrictive and that many supervising teachers did not want them to 'experiment' with their practice. More so, they felt as though some supervising teachers simply expected their student-teachers to mimic their teaching approach. This was an enormous dilemma for many student-teachers.

> Hannah's Science supervisor advocated a text dependent, transmissive view of teaching that represented a marked contrast to ideas Hannah had been developing as a result of her studies in Dip. Ed. and from the positive role model she had described from her own schooling...[she] believed she was 'set up to fail' when she tried out approaches that marked a change from the supervisor's traditional mode of operation. She felt that this was particularly evident when the supervisor chose to provide negative verbal feedback during the class about her progress rather than providing some written suggestions and an opportunity for discussion after the class. (Berry, 1995; p. 38 - 39)

The practicum experience is clearly a most important aspect of science teacher education and needs to be carefully considered by both the universities and the school supervising teachers if beginning science teachers are to embark on their teaching careers with an understanding and confidence of how to teach science for meaningful learning.

Similarly, the importance of the practicum should not be underestimated in influencing the nature of the science teaching and learning that will result when these beginning teachers embark on their teaching careers. Hence, existing science teachers who act as supervisors as well as the university science educators carry an important responsibility in shaping the nature of the science teaching and learning that is already apparent in schools - and how this might change in the future.

Beginning to Teach Science

It is perhaps appropriate to conclude this paper by considering some of the outcomes of science teacher education programs that appear to 'live on' in science teachers once they have completed their qualification.

In recent times there has been a trend for science teacher educators to examine in detail their student-teachers' learning about teaching both during their pre-service teacher education program and into their initial years of teaching. Skamp (1995) was concerned that some of the 'myths' about teacher education and its lack of influence on student-teachers' learning and practice needed to be examined rather than perpetuated. He found that through enrolment in university science and technology units, (elementary) student- teachers' conceptions about science were influenced by the nature of the course work and their practicum experiences. This was important to Skamp because it demonstrated that pre-service programs can be influential in the development of student-teachers' conceptions of science. Clearly, he would hope that this would similarly be translated into their practice when teaching full-time.

In a longitudinal study of (secondary) pre-service science teachers during their first five years of full-time teaching it became apparent that for many science teachers, it took 3 years or more for them to settle into teaching before they began to re-explore the approaches to science teaching and learning that they had developed (and perhaps idealised) in their teacher education program (Loughran, 1992; 1994; 1996). This was largely due to the lack of time and support available to them in schools, and the slow development of confidence and perceived competence necessary to encourage them to feel comfortable in teaching 'against the grain' and to build a science teaching and learning environment that they could both manage and sustain.

It is also encouraging to see our teachers involved in professional development projects such as the PEEL project (Baird and Mitchell, 1986; Baird and Northfield, 1992) which focus on metacognition and active learning. Projects such as PEEL offer teachers opportunities to challenge the often accepted 'passive student learning' approaches in schools and work to genuinely engage their students in their learning. For all of us involved in science teaching and learning, these outcomes offer possibilities for recognising that change is possible and that we should all be working towards helping our students learn and understand science in meaningful ways.

Dawson (1991) captures the wish that many science teacher educators have for their student-teachers (and that I am sure that school teachers have for their pupils too): that they will create classroom and laboratory learning experiences which will encourage their students to actively create new knowledge and understanding of science. Knowing whether or not this wish is realised is closely tied to the way our science education research literature interacts with our teaching and is another reason why research into science teaching and learning is so important to science teacher educators and science teachers.

Conclusion

In an interesting analysis of characteristics of research in science education (in Australia) between 1975 and 1995, White (1997) compared journal articles in RISE (Research in Science Education) to determine changes in style over time. Amongst his findings were that from 1975 to 1995 there had been a shift in research style from experimental to descriptive; that the models of teaching/learning moved from being simple/unspecified to complex and detailed; that interventions had changed from being pre-determined, well-defined, controlled and brief to much more developed, fuzzy, guided and long; that the forms of measurement which were once simple, shallow tests had become interviews and observations of a complex and deep nature; and that the relevance of the research to the classroom had moved from being slight in 1975 to great in 1995.

This shift in research in science teaching and learning, I believe, mirrors, but with some lag time, the shifts in science teacher education programs as there is an increasing emphasis on teaching about teaching for understanding, rather than teaching as the delivery of knowledge and information. I have no doubt that this focus on researching science teaching and learning is crucial to the development of science teacher education programs, especially as, in Australia, the science teacher educators are also the science education researchers. The desire to link research with teaching is a most important attribute and is clear in the work of Berry (1995) when she states:

> As my understanding of the various factors influencing the beginnerteacher experience has deepened, I think about the implications for myself as a teacher educator who works in the same program from which the participants in this project have been drawn...adopting an approach which models the attitude of reflective inquiry which I am seeking to promote is equally as important...exploring the developing pedagogy of [these beginning teachers] has led me to a greater understanding of my own conceptual development. The ongoing challenge is to provide opportunities for student teachers to begin to think about their own. (pp. 74 – 75)

For science teachers I believe the same challenge applies and we should all - as science educators - be working to enhance the opportunities for understanding of our students. One way of doing this is to explicitly link what we can learn from science education research to the way in which we teach science in order to enhance our students' science learning.

Biography of the Author

Associate Professor J. John Loughran holds a position in the Faculty of Education at Monash University as a science teacher educator. His research interests include teaching and learning, teacher education, reflective practice and teacher as researcher. He teaches at all levels in the Faculty of Education from Undergraduate through to Doctoral Level and works closely with many schools in both research and professional development ventures.

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