CULTURAL PERSPECTIVES IN SCIENCE EDUCATION

THE WORLD OF SCIENCE EDUCATION

Handbook of Research in Australasia

- Volume 2 -

Volume Editor: Stephen M. Ritchie

Series Editors: Ken Tobin, Wolff-Michael Roth

SensePublishers

The World of Science Education

CULTURAL AND HISTORICAL PERSPECTIVES ON SCIENCE EDUCATION: HANDBOOKS

Volume 2

Each volume in the 7-volume series **The World of Science Education** reviews research in a key region of the world. These regions include North America, South and Latin America, Asia, Australia and New Zealand, Europe and Israel, North Africa and the Middle East, and Sub-Saharan Africa.

The focus of this **Handbook** is on North American (Canada, US) science education and the scholarship that most closely supports this program. The reviews of the research situate what has been accomplished within a given field in North American rather than an international context. The purpose therefore is to articulate and exhibit regional networks and trends that produced specific forms of science education. The thrust lies in identifying the roots of research programs and sketching trajectories—focusing the changing façade of problems and solutions within regional contexts. The approach allows readers to review what has been done and accomplished, what is missing, and what might be done next.

The World of Science Education

Handbook of Research in Australasia

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SENSE PUBLISHERS
ROTTERDAM/BOSTON/TAIPEI

A C.I.P. record for this book is available from the Library of Congress.

ISBN 978-90-8790-927-7 (paperback)
ISBN 978-90-8790-928-4 (hardback)
ISBN 978-90-8790-929-1 (e-book)

Published by: Sense Publishers,
P.O. Box 21858, 3001 AW
Rotterdam, The Netherlands
http://www.sensepublishers.com

Printed on acid-free paper

CONTENTS

SECTION III: SCIENCE TEACHING AND TEACHER EDUCATION

STEPHEN M. RITCHIE

INTRODUCTION

Science Education Research in Australasia: An Overview

FEATURING SCIENCE EDUCATION RESEARCH IN AUSTRALASIA

This book identifies and surveys the major themes of research conducted in science education within the Australasian region—a region loosely recognized as that which includes Australia and New Zealand plus nearby Pacific nations such as Papua New Guinea, Solomon Islands, Fiji, Tonga, Vanuatu, and the Samoan islands. Unsurprisingly, due to the uneven population distribution across the region, there will be an inevitable concentration of research outcomes from Australia and New Zealand, a contribution that has had a substantive impact on the international community for several decades.

Writing about Australia's international contribution to science education research, for example, Fensham (2008) noted, "Australian academics, perhaps because of our small size as a research community (or because of our eagerness for traveling overseas) have always worked hard at keeping up with what is going on elsewhere, at least in the English speaking countries" (p. 189). This observation was supported by other contributors to the history of the National Association of Research in Science Teaching (NARST) (Joslin et al., 2008) and in the historical accounts of the Australasian Science Education Research Association (ASERA) (White et al., 2009). For example, Gardner (2009) chose the boxing metaphor of "punching above its weight" to refer to Australia's international contribution to science education research to suggest that Australian researchers have made significant contributions to the international field of science education.

Even though there is a long tradition of individual Australasian researchers contributing to international communities of science education (cf. Joslin et al., 2008), the establishment of the field of science education research in Australasia coincided with expansions in teacher education institutions and large-scale curriculum development projects (e.g., Australian Science Education Project, ASEP) in the late 1960s and early 1970s (see Fensham, 2004). The research conducted by the pioneers of research from this period is well represented in this handbook. Yet, more recent advancements in theoretical stances, methodological procedures, and widening topics of interest are privileged throughout.

Selection of topics in such a handbook is always problematic. I have identified topics or themes that appear to me to have currency, longevity, and/or regional significance. In terms of regional significance, there are two chapters in particular that stand out. Elizabeth McKinley and Georgina Stewart review important recent research into Indigenous Knowledge in Chapter 4. They argue that modern indigenous identity has strongly influenced the socio-politics in the region, justifying the study of intersecting knowledge systems and its relevance for school curricula. The second chapter that has salience for many within the region focuses on the problems experienced by rural communities. In Chapter 9, Debra Panizzon identifies the major challenges confronting science teachers who work in rural schools, where student achievement in science is lower than students from city and provincial schools.

I avoided dedicating chapters to research in the traditional disciplines of science; namely, physics, chemistry, and biology. Australasian research is renowned for its contribution to conceptual learning. One chapter focuses on outcomes from the Learning in Science Project in New Zealand (i.e., Chapter 6) while other chapters address conceptual change (i.e., Chapter 11) and the use of metaphor and analogy (Chapter 12) across the disciplines. In general, a cross-disciplinary approach to this handbook of research made much more sense to me because it is arguably more useful for teachers and researchers to have general trends and developments rather than particular discipline-specific idiosyncrasies identified. Similarly, even though Australasian research has made great inroads into the promotion of learning science in primary and early childhood contexts (see White et al., 2009), I did not devote separate chapters to these areas. Instead, I invited contributions on general topics such as practical work, assessment, teacher practice, teacher education, teacher leadership, and out-of-school learning, that might have broader appeal for readers across the various year levels of students and teachers.

From the birth of ASERA, researchers exchanged and developed instruments to assess student attitudes and, somewhat later, aspects of classroom learning environments. Each of these enduring topics of research has a dedicated chapter. The evolution of the science curriculum has not been forgotten. One of the first attempts to improve the perceived relevance of the school curriculum was a science, technology and society (STS) approach. In Chapter 2, Alister Jones explores the tensions and synergies between science and technology in the science curriculum. More recent societal concerns with environmental issues have led to enthusiasm for a science curriculum that addresses sustainability issues. In Chapter 3, Keith Skamp traces the contribution of Australasian science education researchers to environmental education—a current emphasis of the Programme for International Student Assessment (PISA) testing regime in science. Of course, PISA has broadened its perspective of scientific literacy and how it should be assessed. Accordingly, it is timely for Vaughan Prain and Bruce Waldrip to review past, recent and possible future directions of research on representation and learning in science in Australasia in Chapter 5.

The 17 chapters of this volume are grouped into three sections. These are:

I. Introducing Australasian Science Education Research
II. Learners and Learning Science
III. Science Teaching and Teacher Education

Each section is overviewed briefly before Peter Fensham—identified as the founder of ASERA (see Gunstone, 2009; Gunstone & Treagust, Chapter 11 in this handbook)—rightly accounts for the genesis of science education research in Australasia in Chapter 1.

SECTION I OVERVIEW

There are four chapters in Section I. Apart from Fensham's historical account in the first chapter, the other three chapters tackle important curricular issues. Alister Jones traces the impact of the STS approach on the science curriculum. The relationship between science and technology is highlighted, and recent developments in learning science through design activities are reviewed. In Chapter 3, Keith Skamp reviews the vast literature on environmental education. While acknowledging a tension between the different purposes of science education and the environmental education movement in Australasia, he challenges science education researchers to consider whether a pedagogy with greater emphasis on sustainability science that addresses socio-environmental issues might lead to students who are more engaged and environmentally critical thinkers. The final chapter in this section is also politically charged. Indigenous children have typically not performed well on school-based and international tests such as PISA. Some attempts to redesign the curriculum have had mixed success. Yet, simply infusing the science curriculum with Indigenous Knowledge (IK) without addressing at a philosophical level that IK and Western science are different ways of knowing, seems counterproductive. Elizabeth McKinley and Georgina Stewart forecast further research will be directed by Indigenous communities, possibly in partnership with science education researchers.

SECTION II OVERVIEW

Section II on learners and learning contains six chapters. First, in Chapter 5, Vaughan Prain and Bruce Waldrip deal with the fundamental issue of learning representational practices (i.e., interpreting and constructing models, graphs, tables, and diagrams, and integrating these representations with written language) in science classes. Their thorough review challenges researchers to develop standardized procedures and measures to demonstrate effective learning outcomes from pedagogical interventions that aim to develop student learning of the literacies of science.

Influenced by personal constructivist views of learning, researchers based at Waikato in the late 1970s and early 1980s theorized research findings on alternative conceptions in the form of the Generative Learning Model. Beverley Bell, Bronwen Cowie and Alister Jones map the trajectory of this influential research in Chapter 6, and how this research group progressively embraced theoretical stances that were more social and discursive than personal in orientation. Interestingly, they conclude their chapter by suggesting there may be merit in mixing ontologies associated with research in learning science.

Despite enduring interest in attitudes to science by science education researchers, it is surprising, as Renato Schibeci points out in Chapter 7, that few studies have used empirically validated instruments for students who are studying science in Australasian classrooms. Even the PISA testing regime appears in need to articulate more clearly the theoretical underpinnings of the attitudinal instruments it uses. It would seem there is much scope for Australasian validation studies in attitudes to science. While Schibeci rightly identified much needed research activity in validating attitudinal instruments, Australian researchers have led the way in developing valid and reliable learning environment instruments. Barry Fraser reviews the major developments over the last 25 years in learning environment research in Chapter 8. Fraser identities two areas worthy of further research in the field; namely, qualitative perspectives of classroom learning environments, and the application of learning environment instruments to help improve pre-service and inservice teacher education programs.

In Chapter 9, Debra Panizzon details the case that there is low equity in science achievement results for rural and remote students in Australasia. After surveying current research in addressing such inequity, Panizzon asks: are there intrinsic differences in teaching science in rural and remote communities or are the results best explained by context? Given that school systems are focused on engaging students from all contexts in relevant and meaningful activities, providing additional resources for rural communities such as visits to science-related educational sites and extension activities is likely to attract increasing support.

Léonie Rennie takes up the issue of out-of-school visits in Chapter 10. In this chapter, Rennie exposes the dilemma for many educators in museums, field centres, and other interactive science centres that entertaining exhibits and activities may not engage children as critical thinkers. While teachers can enhance the effectiveness of out-of-school visits by careful pre-visit planning, focused activities during the visit, and post-visit discussions, future research might focus on understanding more fully how visits to out-of-school venues can promote scientific literacy and active citizenship.

SECTION III OVERVIEW

Section III on science teaching and teacher education includes eight chapters. While aspects of some of these chapters easily could have been included in the previous section, they are presented here because, as Richard Gunstone and David Treagust argue in Chapter 11, conceptual change researchers in Australasia focused their research on teacher development and change, and supporting student and teacher change. After reviewing the substantive contribution of Australasian research to the international field, Gunstone and Treagust remind us that these outcomes have had little impact on actual teaching practices identified across the educational cultural differences in several countries. This led them to identify at least two areas for further research. These were: to explore the effects of inclusive approaches to conceptual change that are based on multi-dimensional perspectives and diverse teaching approaches; and to examine the efficacy of different teaching approaches in classroom settings that can be implemented independently of researchers.

Peter Aubusson, David Treagust and Allan Harrison extend the review on conceptual change by focusing on learning and teaching science with analogies in Chapter 12. They note than although analogy has featured so prominently in the development of the sciences, research into the classroom application of analogy for learning science is a much more recent phenomenon. Work by Australasian researchers on the cogeneration of analogies and metaphors have produced new insights into learning and teaching science, but there is scope for much more research. Aubusson et al. identify other areas for further research. Two appear to be particularly interesting; namely, independent student use of analogies, and the role of metaphor and analogy in large-scale collaborative teams of teachers effecting pedagogical change.

Practical work is more than laboratory activities; it also includes such out-of-school work as excursions and astronomy nights. In Chapter 13, Bev France and Mavis Haigh take a refreshing approach to their review of Australasian research. They blend their own narratives of their experiences as students, teachers and teacher educators. As well as providing personal insights into their experience and research programs, we are reminded that the laboratory emphases of the major curriculum development projects in the late 1960s had a global impact on the research that followed. They conclude their comprehensive account by suggesting that inroads can be made by focusing attention on ways to help teachers develop research-informed pedagogy of practical work based on socio-cultural perspectives of learning.

Alignment of the curriculum, pedagogy and assessment practices has become a major goal in education. Bronwen Cowie notes in Chapter 14 that Australasian researchers have contributed substantively to broadening the role of assessment in science education reform. Assessment for learning practices and research foci will continue to evolve, especially in the context of changing emphases in the science curriculum and of scientific literacy.

The last three chapters of this section do as the title of Chapter 15 suggests: focus on the science teacher. In Chapter 15, Russell Tytler and Linda Darby review Australasian research that has focused on improving the quality of science teaching. While there will always be problems and debates with descriptions and typologies for what constitutes effective science teaching, Tytler and Darby identify exciting (emotional) topics for further research. They rightly identify Butler et al. (1980) as the pioneers of video analysis of science lessons, and nominate possible directions for further video-based research as: teacher retention, development of pedagogies relevant to curricular reform, and the transformation of research findings to support teacher development. Another point they make is the need for researchers to theorize the process of engaging teachers in conversations about pedagogy, and in supporting the transformation of classroom practice.

Ritchie and Hudson also argued that greater attention was needed for researchers to specify and/or develop theoretical stances in describing teacher leadership practices in Chapter 16. They note that although innovations have succeeded because teacher leaders influenced and supported their colleagues, few studies have dealt with the issue of leadership at a theoretical level. To make headway in promoting new developments for science teaching practice, as recommended by Tytler and Darby, researchers will need to embrace the most recent theoretical work on teacher leadership, especially those perspectives that link variants of distributed leadership with collaboration.

In the last chapter of this volume, John Loughran reviews the significant contribution made by Australasian science education researchers in perhaps the most important field of pre-service teacher education. He notes that while self-study has been a breakthrough area of research at the individual level, where teacher educators have come to learn the value of practicing what they preach, it is at the collective level that further advances in research are likely to be observed.

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SECTION I: INTRODUCING AUSTRALASIAN SCIENCE EDUCATION RESEARCH

PETER J. FENSHAM

1. THE GENESIS OF SCIENCE EDUCATION RESEARCH IN AUSTRALASIA

Although the sciences were being taught in Australian schools well before the Second World War, the only evidence of research studies of this teaching is to be found in the report, published by ACER in 1932 of Roy Stanhope's survey of the teaching of chemistry in New South Wales and a standardized test he had developed. Roy Stanhope was a science teacher with a research masters degree in chemistry. He had won a scholarship to go to Stanford University for doctoral studies, but returned after one year when his scholarship was not extended. He went on to be a founder in 1943 of the Australian Science Teachers Association (ASTA), which honours this remarkable pioneer through its annual Stanhope Oration. In his retirement Stanhope undertook a comparative study of science education at Macquarie University for a research masters degree, awarded in 1974.

By 1964 ASTA had conducted another survey (Stanhope again involved) that revealed national statistics about secondary teachers of science that were alarming, such as 30% of the 2,918 respondents had no tertiary qualifications in science. At that year's meeting of the Australia and New Zealand Association for the Advancement of Science (ANZAAS), Stanhope and ASTA used this survey's findings to argue a case for an Australian Science Education Foundation. This Foundation would act in Australia to stimulate improvements in science education in a similar manner that was happening in Britain and USA through the Nuffield Foundation and the National Science Foundation respectively. A year later J. M. Genn and R. P. Tisher, both of the University of Queensland, published in the **Journal of ASTA** (**ASTAJ**, No.31, May 1965), respectively, another survey study and a paper entitled "Research in Science Education". Tisher's paper argued that the proposed Australian Science Education Foundation should also be charged with fostering and initiating research in science education. Papers reporting research studies by Power, Broadhurst, Tisher, and Foster appeared in later issues of **ASTAJ** in 1966 and in 1967.

The return to Australia in 1967 of David Cohen with a PhD from Michigan State University to a post at Macquarie University and to the Editorship of **ASTAJ** formalised a regular *Research Section* in the **Journal** in 1968 with Tisher as its sub-editor

With the idea of a Foundation languishing despite these keen pressures, Monash University then, quite independently, played the significant card in developing science education as an Australian field of research. Its first act in 1967 was a radical one. It appointed me, a Reader in Physical Chemistry at the University of Melbourne, to a Chair in Science Education, the first such appointment in Australia.[1] My research area was solid state chemical physics, but earlier in my

S.M. Ritchie, The World of Science Education: Handbook of Research in Australasia, 9–15.

career, after post-doctoral studies in that area at Princeton University, I had held a Nuffield Sociological Fellowship at Cambridge University. This enabled me to study social psychology and social anthropology and undertake an ethnographical study of a factory community experiencing rapid technological change.

I thus had an unusually wide background in natural and social science research, and had shown evident educational interest by conducting, as a chemistry lecturer, a small study of university assessment based on Bloom's taxonomy.[2] Nevertheless, I had neither the school teaching experience nor the post-graduate qualifications in education that were customary at that time in departments and faculties of education. This lack of a formal background in education raised considerable suspicion among some of the existing staff, who tried to make it clear, for instance, that there was no place for subject content in a Faculty of Education's teaching or research programmes. As it subsequently turned out, 10 of the first 20 PhDs to be completed at Monash were in science education.

The other important acts that enabled the genesis of research in science education stemmed from Monash's interest, as a new university, in providing conditions that led to the rapid development of a research reputation. In my case this meant establishing a research group and a research programme as quickly as possible. Monash enabled these through a conjunction of structural features that did not exist at that time in other universities. For example, Monash was the first Australian university to be based on faculties rather then departments. The seven initial deans were not only responsible for developing their faculties, but also worked very directly with the vice-chancellor, as his first tier of academic authority, in developing the university as a whole. The faculty was the administrative and financial unit for the academic life of the university.[3] Furthermore, the funds to cover a faculty's budget for a year were available to the dean for disposal with a "power of virement" which meant budget lines were interchangeable. This financial flexibility gave the deans great power, and for more than a decade while the university was growing, they had free funds through inevitable "salary savings", to support various initiatives. This latter flexibility was not possible in other universities, where salaries and any savings in relation to them remained in the university's central budget.

Accordingly, very early in the Faculty of Education's history it was decided, as a first call on the budget, to set aside the equivalent of a Lecturer's salary to bring interesting and distinguished visitors to the faculty. Among these visitors of interest to the science education research group were Deryck Hoare (Scotland: a first ever review of first year university teaching of chemistry in Australia), Robert Gagne (USA: with whom Dick White very successfully collaborated), Merle Wittrock (USA: whose paper on generative learning theory with Roger Osborne became a seminal reference), David Layton and Douglas Barnes (England: an ongoing link with the Centre at Leeds University), Audrey Champagne (USA: developed with Dick Gunstone the P.O.E.), Rosalind Driver (England), Pinchas Tamir and Ehud Jungwirth (Israel), Svein Sjøberg (Norway), Heidi Kass and Gaalen Erickson (Canada). Joe Novak (USA), and Ference Marton (Sweden) were influential shorter visitors. Many of these persons, in turn, hosted Monash staff (on study leave) and students as post-doctorals, an outstanding return for a university where many of the staff had no university experience other than Monash.

Another outcome from the Committee of Deans was their decision to offer some research scholarships funded at a higher level to qualified persons who had been in established employment for several years. For the Education Faculty this opened the door to experienced teachers to undertake full time graduate studies without the severe loss of salary that the normal PhD scholarships would mean. Among a number of these very talented persons, Richard White and Leo West, experienced science teachers, were able to enrol. In addition, four young lecturers with science backgrounds embarked on research studies at the masters or doctoral level.

This rapid emergence of a viable research group attracted attention in Victoria and interstate, and new graduate students appeared from unexpected backgrounds. Two of these came to the Faculty with first class honours degrees in science but no prior study of education. Russell Linke from South Australia was one of these students. He dabbled with doing a study on conceptions of life and living, which could have accelerated our subsequent strong involvement with research into students' conceptions of science phenomena. However, he was a canny character and settled for a safer topic of graphical skills in relation to science, for which he could replicate the design that Richard White had pioneered in relation to mechanics.

Russell's special contribution to the research programme at Monash (and to the science education part of it in particular) lies not in his own research but in the contribution he made to its collegial atmosphere. As a foundation student at the Flinders University in Adelaide he had been, as a freshmen, the President of the Student Representative Council. As such, throughout his undergraduate years, he had had a desk in the temporary buildings of the Science Faculty which gave him a sense of equality with the Dean and other staff that was quite unusual in undergraduates. When he arrived at Monash, he expected to treat, and be treated by, the dean, the professors and the lecturers on equal terms. These expectations rapidly spilled over to the other full time students.

By 1970, the substantial nucleus of young staff and full time graduate students undertaking postgraduate research in science was ready to start sharing their work beyond the lively forum within Monash itself. Some master's degrees by research had been completed and the first doctorate (Richard White) was imminent. Taking advantage of the existence in Melbourne of the newly established project to develop junior secondary science materials, ASEP, the Monash group invited all persons known to be involved or interested to a meeting at the ASEP headquarters to share research ideas. Twenty six persons attended and decided to begin a newsletter for exchanging ideas more widely and momentously to launch the *Australian Science Education Research Association, ASERA,* the second such body (after the National Association for Research in Science Teaching (NARST) in USA) in the world dedicated to research in science education.[4]

Macquarie, the only other university with a nucleus of science educators, David Cohen, Bill Butts, Rex Myer and Roy Stanhope, agreed to host the second ASERA conference. It was then back to Monash but by the fourth ASERA in 1973 the field was moving so well that only once again in 40 conferences has Monash been host.

The founding members were keen that ASERA should have the encouragement of fledgling researchers as its primary purpose and in a manner akin to the "democratic" culture that the Monash group enjoyed. Accordingly, ASERA soon developed a structure and a culture for its meetings and publications, that were rather inverse to most academic associations. There were no office bearers other than the Editor. Local groups, in turn, simply volunteered to host the annual conference. There were no plenary speakers and all presenters (new graduate students and established scholars) were given the same time – 40 minutes: 20 minutes presentation and 20 minutes for discussion. In due course, when profits from the conferences began to accumulate, it was decided to give some funding to participants, but this was restricted to persons presenting at a conference for the first time. No funding support has been provided to established scholars. Even when incorporation became a necessity in the 1990s and an executive board needed to be elected most of this culture has persisted. *Research in Science Education*, **RISE**, the Association's journal, moved in 1995 from refereed papers that had been presented at the annual conference to an open international journal for research and is now highly accredited.

The dominant overseas paradigm for research studies in the early years was quantitative analyses of data from quasi-experimental and other designs. The Monash research group had strong backgrounds in science and mathematics and so were quite comfortable in this paradigm. Indeed, White, Gardner and West were each able to make and publish contributions to the statistical methods used to analyse their results. Furthermore, these three were applying and testing the theoretical positions of Robert Gagné, Jerome Bruner, David Ausubel. This meant the group was becoming familiar with three of the four leading theorists, at that time, whose ideas were influencing science teaching and learning and curricula. Praxis, the practice of research and the role of theory, thus characterized the group's research efforts from the very beginning. Only, the ideas of Jean Piaget of the important theorists was missing; but a decade later the research at Monash was greatly indebted to him, not so much for his stage theory of learning but for his interview method of eliciting data from individuals.

White (1991) pointed out two early strands of the research at Monash independently provided roots for the constructivist emphasis that was to become a major Australian contribution to international research in science education. In pursuing (with Leo West) Ausubel's dictum about the importance of what the learner already knows, I drew attention to the possibility that this prior knowledge could have both establishing and distorting effects on what was now to be learnt (Fensham, 1972). At the same time White, Beeson, Linke and Trembath, were exploring Gagne's notion of learning hierarchies which also emphasized the importance of prior knowledge.

The 1977 meeting of ASERA marked a coming together of these two strands, and in addition included reports involving data from Piagetian-like interview procedures that was soon to provide the gateway to students' prior knowledge. The meeting was also the scene of the personal meeting between John Gilbert (University of Surrey) and Roger Osborne (University of Waikato), that flowered very quickly into a spectacular advance in interview research procedures for investigating the prior understandings learners bring to science classrooms (Osborne & Gilbert, 1980).

1977 thus marked the beginning of a most fruitful and ongoing trans-Tasman collaboration that was soon formalized with ASERA becoming the Australasian Science Education Research Association. In the Monash group that year also marked the first recognition for funding by the national *Educational Research and Development Committee* of ethnographic research methods for a major study of science classrooms (see Fensham & Ingvarson, 1981).

Paul Gardner, after his initial Brunerian study moved into the area of students' attitudes to science and science education. Two papers of his in the mid 1970s became touchstones for this type of research which had been renowned for poor instrumentation and poor design (see for example, Gardner, 1975). He also was an early (indeed a too early) contributor to the key role that language plays in learning science. Gardner's (1972, 1975) excellent work that had, alas, been overlooked when psycho-linguistic and socio-linguistic studies in science classrooms became vogue in the 1990s. I began to use content analysis to explore the social dimensions that were included or excluded in science texts (Fensham, 1973), beginning a still continuing strand of studies on the political nature of the science curriculum, best identified by my 1985 paper, *Science for All.* In this same period, Rod Fawns, a doctoral student, began to regularly present historical studies of science curriculum developments in Australia. By the end of its first decade the group at Monash had incorporated a much wider range of research procedures than existed in 1970, and the use of these was evident in the papers being presented at ASERA's annual conference.

Throughout the 1970s and 1980s, with 19 universities in Australia, Monash was producing one third of all doctoral degrees in education, and its Education Faculty was the only one whose student load was more than 50% in master's and doctoral programmes. Its many graduates in science education went on to positions in a number of other universities and CAEs and in state ministries of education. Two of them, Barry Fraser and Campbell McRobbie, were thus poised in Western Australia and Queensland, respectively, to establish very strong research centres when their CAEs were granted university status. The former centre went on to give great national leadership when it was identified by the Commonwealth Government as the host for the Key Centre for School Science and Mathematics, the only one of these national Key Research Centres associated with education.[5] Russell Linke and Leo West, respectively, became key figures in the *Disciplinary Reviews of Engineering* and *Science and Mathematics Teacher Education* that the Commonwealth Department of Education used in the later 1980s to raise issues of standards and quality in higher education.

Dick Gunstone's development of the POE (Predict-Observe-Explain) and its use in a number of research studies saw the emergence of a number of other powerful probes of prior understanding and metacognition, like concept mapping, drawings, fortune lines, and word association, that naturally led on to studies that explored conceptual change and the conditions that facilitate it. John Baird's doctoral study with Richard White in a biology teacher's classroom was the inspiration for them, together with Ian Mitchell, a chemistry teacher and part-time Methods' Lecturer, to launch a collaborative action research project with a number of teachers at Laverton High School. This project, a year later, became PEEL, the Project to Enhance Effective Learning, that for more than 20 years has been the source of a remarkably rich sharing of teachers' knowledge that extends far beyond science teaching (see White, 1988). In addition to influencing hundreds of teachers and schools in Australia, the ideas and principles of PEEL have found fruitful responses in Sweden, Denmark and Canada, arguably making it Monash's most significant contribution.

Some early work by myself on Technology as Applications of Science became a basis in the later 1980s for supporting Science/Technology/Society (STS) type curricula for school science. Following the recognition of Technology in the early 1990s as a new subject for schooling, Paul Gardner, (1994, 1995) extended the work of David Layton (England) and Edwin Layton (USA) on the complex relations between Technology and Science in two very important essays in the *International Journal of Technology and Design Education* (1994, 1995).

The Monash trio of White, Gunstone and myself pioneered, in the late 1980s, one final breakthrough for science education research when the *Australian Research Council* awarded them the first, continuing (three years) research grant awarded in education. In a reflective piece, they discuss how their research had evolved over their years together at Monash (Gunstone, White, & Fensham, 1988).

PUBLICATIONS

A number of major publications by Monash authors should be noted as evidence of the energy and vitality that marked this genesis period.

Gardner, P. L. (Ed.). (1975). *The structure of science education*., Victoria, Australia: Longman. *(Lee Cronbach of Stanford University, in a review, commented that he knew no single group in USA that could produce such a volume.)*

White, R. T., & Tisher, R. P. (1986). Research on natural sciences, In M. Wittrock (Ed.), *Third AERA handbook of research on teaching* (pp. 874–905), New York: Macmillan.

Fensham, P. J. (Ed.). (1988). *Developments and dilemmas in science education*. Brighton, England: Falmer Press. *(The first volume in the field with international authors)*

White, R. T. (1988). *Learning science*. Oxford: Blackwells.

Fensham, P. J. (1991). Science and technology. In P. Jackson (Ed.). *Handbook of research on curriculum.* (Chapter 28, pp. 789–829). New York: Macmillan Publishing Company. *(An AERA project)*

White R. T., & Gunstone, R. F. (1992). *Probing understanding*. London: Falmer Press. *(This introduction to these research methods predated by a decade a similar book in USA)*

Fensham, P. J., Gunstone, R. F., & White, R. T. (Eds.). (1994). The *content of science education*; *A constructivist approach to its teaching*. London: Falmer Press.

NOTES

[1] The University of NSW soon after appointed Austin Hukins to a similar chair, and he made slower, but important progress in developing the research field in NSW.
[2] This was so unusual at the time that it was reproduced in full in *Nature* (1965) *No.194,* 142-4.
[3] Elsewhere the academic department, rather than the faculty, was seen as the academic unit. Staffing was a budget item, centred in the university administration, leaving department heads with only the non-staffing budget to operate.
[4] This launch interestingly preceded by some months the establishment of the Australian Association for Research in Education, AARE, as an overall national body for educational research.
[5] Fensham was asked to assess the six applications for this Key Centre, after his own university was not prepared to nominate the Monash group, not wanting its first Key Centre to be in Education.

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2. EXPLORING THE TENSION AND SYNERGIES BETWEEN SCIENCE AND TECHNOLOGY IN SCIENCE EDUCATION

INTRODUCTION

This chapter explores the way in which technology has been introduced through and by science educators in Australasia in the last 25 years. A number of themes have arisen in this time from using technology to engage students in science, exploring the impact of science on society through technology, considerations of the nature of technology in relation to science, and the exploration and development of technology as a subject in its own right. In this process student and teacher perceptions of technology were explored, as well as teacher change and the influence of teacher/ subject culture through to sustained classroom research and school change and the way in which the introduction of a new subject like technology can influence our thinking around science. In the early 1980s technology was introduced in terms of science, technology and society as well as playing a role of providing applications or examples of science in action. The underlying assumptions were that technology was applied science. In the late 1980s debates began to arise around the nature of technology, its place in the curriculum and its relationship to science. In the mid to late 1990s until 2007 we have seen a distinct move to examine technology in the classroom and to use the lessons from science to explore the teaching, learning and assessment of technology. Throughout this process research in science education has informed our ideas about technology, and our exploration of technology with teachers and students in the classroom has influenced our approaches to science education, in curriculum development, teacher development, classroom research, student learning and wider school reforms.

In exploring the relation and tension between science and technology in Australasia I have not attempted to review all technology research and development in that time but rather examine the development of technology where people have been involved in both science and technology education. A review of the development of technology education as an area of research and development in its own right in Australasia is for another publication.

SCIENCE, TECHNOLOGY AND SOCIETY

The 1980s in Australia and New Zealand saw an attempt to include the theme of science, technology and society (STS) in the research and curriculum agenda. Fensham, (1987), identifies eleven dimensions or aspects of STS learning. These

S.M. Ritchie, The World of Science Education: Handbook of Research in Australasia, 17–27.

are: the relation between science and technology; technocratic/democratic decision making; scientists and socio-scientific decisions; science/technology and social problems; influence of society on science/technology; social responsibility of scientists; motivation of scientists; scientists and their personal traits; women in science and technology; social nature of scientific knowledge; and characteristics of scientific knowledge (scientific methods, models, classification schemes, tentativeness). The STS movement began due to a combination of factors, including the growing concern in the 1960s that science education had become divorced both from its social origins, and from the social implications of scientific endeavour. This was often expressed as the "social relevance of science" (Fensham, 1987, p. 1). There was also a push for science education to become more technology related. This early shift in increasing the relevance of science through being more technology related was used by Jones (1982) to explore technological applications of physics as a means of providing real-world examples of physics concepts. This approach was limited to a greater focus in technology but did not pick up the social aspects. However, this notion of expanding the technological focus within science allowed for exploration of technology to expand problem solving in science.

Corrigan (1999) explored the consequences for teaching and learning of the introduction of STS perspectives into a senior secondary chemistry curriculum in Victoria. Her research explored the ways in which the introduction of social aspects of chemistry influenced how teachers and students perceived school chemistry. This also included exploring the purposes for including technological and industrial tasks in chemistry curriculum and the way these purposes were perceived by teachers and students.

The introduction of biotechnology as an area of research and development, including curriculum development provided a means to develop a much more research focused agenda around science, technology and society. Advances in biotechnology have social, political, economic and wider cultural implications and present society with ethical issues and dilemmas which require informed citizens capable of contributing to public debate. An improved understanding of socio-scientific issues amongst young people will help to ensure they have an informed, defensible view and that they understand, for example, the rationale for national initiatives to combat environmental issues involving genetically modified organisms (Dawson, 2003).

Part of the reason for including social and technological issues is to introduce values and ethics into science. Conner (2003) has provided an on-going commentary and analysis of the efficacy of bioethics teaching in New Zealand, with a focus on the implementation of such programs in senior biology classes. Conner's view that students need to develop critical thinking skills when working through biotechnological issues and her recent research in this area, provides some useful ideas for developing this component of biotechnology education. With respect to learning about bioethics, Conner and Gunstone (2004) propose that better understanding of bioethical issues will occur when students are able to re-evaluate their personal ideas and beliefs and its relevance to the issue in question; for example, Conner's analysis of the efficacy of 16 final year high school biology students documenting their conscious knowledge of learning when they wrote essays about cancer.

Recent studies of the attitudes of high school students to biotechnology found that the ethical problems generated by biotechnology interested them but that many students are unable to distinguish between current and potential uses of biotechnology (Dawson & Schibeci, 2003). Student-centred inquiry approaches to bioethics education that build on students' existing or prior knowledge are therefore desirable (Conner, 2005). In such approaches, the teacher's role is facilitative and includes assisting students to examine and evaluate controversial issues critically, from multiple perspectives, using a good decision-making model (Conner, 2003, 2007).

It seems clear that students need opportunities to develop, reflect on, and justify their bioethical values (Dawson & Taylor, 1999). Dawson (2003) identifies the multiple skills involved in students' ethical decision-making: ethical sensitivity (in identifying the dilemma); ethical reasoning (identifying and weighing up arguments for and against different decisions); and ethical justification (reaching and justifying a decision). While approaches derived from STS programs; for example, case studies, structured debates, oral presentations and scenarios, can be adapted to promote student questioning and decision-making about societal issues, many of these do not delve deeply into the social and ethical aspects (Conner, 2002).

Research has examined social issues in science education but there has not been a large amount of research on STS as a sustained research agenda in Australasia. Part of the reason is that those involved in the early days of STS and similar areas focused their attention on technology as a developing curriculum area in the 1990s and beyond.

PERCEPTIONS OF TECHNOLOGY BY SCIENCE TEACHERS

As technology was being increasingly linked with science education and as an area of study in its own right, concern was raised as to what were teachers' and also students' perceptions of technology. Studies were undertaken on perceptions of technology but this section focuses on science teachers' perceptions of technology.

In the study conducted by Jones and Carr (1992) on teachers' perceptions of technology and technology education they found that all the science teachers who were interviewed saw technology education in terms of applications of science. In terms of teaching, technology was perceived to be a vehicle for teaching science and often something extra to the conceptual development in science. There was concern expressed about non-science teachers incorporating the scientific aspects of technology into their lessons. At the time of the study in both the primary and intermediate school setting teachers were trying to integrate computers into their classrooms. In the primary school there was one computer per class and at the intermediate school the computers were located in a resource area. Many of the teachers at the primary and intermediate school viewed technology in terms of computers. For these teachers technology meant using computers or other technology to solve problems. Although they might be aware of the range of technology they tended to focus on computing. For example, as stated by one teacher, *not using pen or paper but using computers to solve problems*. Teachers also mentioned problem solving in relation to finding out how things work. When talking about technology, teachers have mentioned problem-solving both in the context of using computers and finding out how things work. Technology is seen as a mechanism for solving a problem or as a vehicle for approaching a particular type of problem solving; that is, finding out how things work, particularly in science at the secondary school level.

Moreland (1998) reported that although the teachers stated they needed to learn more about the teaching of technology, they felt they had enough skills and understanding to be teaching technology and could do it in the classroom. One teacher with a science strength set the students applied science tasks (design a hot balloon after studying flight). Technological principles were not involved. The criteria were in terms of why things happened and a narrow focus of outcomes. Northover (1997) noted that all the science teachers she worked with viewed technology as being applied science and technology as skills and skill development. The teachers went for minimal change and added technology into existing programs rather than developing new ones or new learning outcomes. She found that these teachers generally expressed an interest in technology education and commented on the motivational aspects of technological activities. Teachers often saw changes in their perceptions of technology and technology education as a means of better understanding the curriculum document. However they did not see the import of the development of a coherent technological knowledge base to their own learning and teaching practice. The dominant science sub-culture in schools proved to be a powerful conservative influence. Teachers who evidenced a changed view of technology and biotechnology at earlier stages throughout the teachers' development by the end had often reverted to the perspective held initially. In fact, where teachers did make changes to their perceptions initially the cognitive dissonance set up by the disparity between their views and their practice was often resolved by reverting to a previously held view.

The strategies developed by the teachers in their classrooms when implementing technological activities were often positioned within that particular teacher's teaching and subject sub-culture. These sub-cultures are consistent and often strongly held. The sub-cultures had a direct influence on the way the teachers structured the lessons and developed classroom strategies. Teachers developed strategies to allow for learning outcomes that were often more closely related to their particular subject sub-culture than to technological outcomes; for example, science and language. Teachers entering areas of uncertainty in their planned activities often reverted to their traditional teaching and subject sub-culture. Their views of assessment, their expectations of the students, and their views of learning, influenced possible learning outcomes identified by teachers in technological activities. When students were carrying out technological activities teachers often reverted to learning areas they were comfortable with for identifying possible learning outcomes rather than technological outcomes. It would appear that the introduction of a "new" learning area in schools, such as technology, is problematic. Teachers' existing sub-cultures in terms of teaching and learning, subject area, and school, in association with their concepts of technology, influence the development of classroom environment and strategies, and consequent student activities.

INTRODUCING TECHNOLOGICAL APPLICATIONS IN SCIENCE

In an attempt to increase the relevance and authenticity of science the introduction of technological applications were seen as a means of achieving this. Research was carried out by Jones (1988) into the effect of introducing technological applications on students' concepts of physics. Using such applications as earthquake monitoring systems and baby breathing monitors, it was found that the students indicated that these technological applications helped them to remember scientific concepts involved. No change was recorded, however, if the applications were used as an add on either at the beginning or end of a lesson. The students also commented that the use of such technological contexts also provided frameworks for the construction of further scientific concepts to those specifically targeted. Another important outcome from this research was the significant increase in the students' level of confidence, interest and enjoyment in science generally. This was a factor noted by both the students and their teachers.

Research in science education that explored the use of technological applications for the teaching of science, suggests such contexts do have a positive effect on students learning of scientific principles and concepts (e.g., Jones & Kirk, 1990; Rodrigues, 1993). Care must be taken however, that the technological context used is appropriate to the students and the scientific content, and that it is presented as an integral part of the learning experience rather than an add on for the sake of sparking interest. For example, Jones and Kirk (1990) qualify their statement regarding how a technological focus enhances the learning of science concepts for most students by stating the need for the context to be linked to suitable teaching sequences and the context integrated into the lesson sequence rather than being used for illustrative purposes.

Rodrigues's (1993), research included exploring the role and effect of context on female students' learning of oxidation and reduction. Using such technological applications as breathalysers, and hair perming and colouring systems as contexts, Rodrigues found that not only did students become more interested in the scientific concepts of oxidations and reduction, but they also showed a large increase in the number and quality of classroom interactions both with each other and the teacher. These interactions took many forms, including direct questioning and discussion centred on both the functions and use of the application and the scientific concepts involved (Rodrigues, 1993). The researcher's observations were that the students appeared to take "control of their learning" (Rodrigues & Bell, 1995, p. 807) and teacher, student, and researcher statements all appeared to suggest that the students experienced an increased conceptual understanding of redox reactions.

TECHNOLOGICAL PROBLEM SOLVING IN SCIENCE CLASSROOMS

There have been many attempts to introduce technological problem solving in science classrooms. However, extensive classroom observations undertaken in science classrooms when technology problems have been introduced have shown that the science classroom culture and student expectations appeared to influence strongly the way in which students carried out their technological activities (Jones, 1994). The students in the science classrooms involved in this research enjoyed carrying-out technological problem solving and their teachers reported considerable enthusiasm for these activities. The main conclusion was that science classroom cultures needed to be understood as greatly affecting performance in technological problem solving. Students' expectations of classroom practice were influenced by subject subcultures. For example, throughout the technological activity which was situated in a science classroom and timetabled slot, the students played by the "rules" of the science classroom. Their perceptions of the activities they were to be involved in were significantly affected by prior concepts of "project" work in science. The focus throughout the unit was therefore primarily in terms of collecting information to present to the class. Students often did not continue with explorations of wider social issues as they did not see this as relevant to their notions of science. Jones and Carr (1993) indicated that the majority of students in the science classroom limited themselves to using science resources even though they had been encouraged by the teacher to use outside resources. The solutions that the students sought were often in terms traditional solutions utilised in their prior experiences of the science classroom. When questioned, these students often stated clearly that they could have done more towards solving their problems, but they consciously limited themselves to what they considered was appropriate within the science classroom. Students often stated that they learnt scientific concepts when undertaking the technological activity, and appeared to view this as the legitimate learning outcome for the activity.

Forret (1997) investigated the early learning of electronics. He used problem solving and contextual approaches to introduce electronics to students. He found that students had an interest in electronics, had enhanced practical competence in constructing circuits and enhanced problem solving. Like Forret, Hampson (2000) noted that students developed greater problem solving skills when engaged in design activities. Ginns, Norton and McRobbie (2005) highlighted that science learning outcomes can be identified by some students in technological activities. These learning outcomes were related to work that the students had covered earlier in the year. However, Norton, McRobbie and Ginns (2007) noted that opportunities for extracting science principles from technological activities have not been maximized. Norton et al. (2007) indicate that introducing technology in science allows students to think for themselves, apply logical thinking, be creative and allow for student autonomy.

When technological problem solving and design activities are introduced into science classrooms, students are interested, enjoy the experience and in many cases learn some scientific concepts (see Roth, Tobin, & Ritchie, 2001). There is very little evidence of transfer of scientific knowledge to technological solutions and little understanding of the processes involved. The technological process adopted by the students is somewhat fragmented and appropriate solutions are not forthcoming. The culture of learning in science classrooms does not appear to lend itself to helping students develop technological capability or intend technological literacy. The introduction of technological problem solving into science classrooms needs careful consideration if technological literacy is a desired learning outcome in science.

TECHNOLOGY IN THE SCIENCE CURRICULUM

The late 1980s and 1990s saw the greater inclusion of technology as an area of study in Australian and New Zealand science curricula. Internationally there was also an emphasis on the inclusion of technology as a vehicle for the learning of science. However generally science curricula portray a narrow view of technology. Such a narrow view of technology relies on a concept of technology as very much focused on applied science. As has been stated elsewhere (Bell, Jones, & Carr, 1995), the treatment of technology as embedded in science is cause for concern as it means that other forms of knowledge, including technological knowledge, which are all essential for technology, are not apparent. It also excludes many technological innovations and developments that have no direct links to science as a discipline. For example in the early levels of the science curriculum in New Zealand the primary reason for introducing technology was for the purpose of clarifying and demonstrating the scientific principle. At higher levels of the curriculum the focus shifted to that of investigating in a very general way the relationship between science and technology. Emphasis was now placed on acknowledging and understanding how technological advances have aided or in fact enabled, the development, or major rethinking of scientific ideas. The way in which scientific principles have provided crucial knowledge for technological development and advance is also highlighted, for example, the development and uses of genetic finger printing. When there was a focus on learning how technological artifacts function, this was in terms of scientific principles only, ignoring technological and other knowledge bases crucial to the successful functioning of technological artifacts, systems and environments. The principles behind technological innovation are perceived to be only those belonging to science. There was some opportunity within this aim to see how technological developments impact on scientific knowledge, and vice versa. This opportunity is constrained to those technologies fitting the applied science notions of technological developments. There is also opportunity for the exploration of the effect of technological development of society, however it is specifically stated that the means of such an evaluation should be through the application of scientific knowledge.

France (2007) has taken a leading role in biotechnology education in Australasia. The development of a scientifically and technologically literate citizen has been the goal of educators and biotechnology provides a fruitful context for this. In most international curricula biotechnology appears within senior science and biology and correspondingly its classroom implementation provides examples of technology as applied science. However, this narrow focus of biotechnology may limit the exploration of socio-political or ethical dimensions of biotechnology classroom programs, and provides limited opportunities for students to develop rich scientific and technological literacies.

France and Bolstad (2004) found that the position of biotechnology in science curricula internationally tended to place it within an applied science (Technology as applied science) framework. An expression of such applied science examples are microbiological processes being identified within human health and disease, examples to illustrate anaerobic respiration (bread and ginger beer making) and the application of microbial degradation in waste disposal and composting. As they note what is missing from most of the curricula are opportunities for discussion of socio-political issues as well as values inherent in technological processes. This positioning of biotechnology in this way means that technology itself is underplayed and also the chance for students to develop a greater understanding of the relationship between science and technology and the values inherent in this.

In an examination of science curricula, biotechnology tends to be seen at the higher levels of the biology curriculum and mainly to do with genetic manipulation (France & Bolstad, 2004). Biotechnology in terms of GM debates can put its inclusion in the curriculum more towards the discussion of controversial issues rather than consideration of a broader understanding of biotechnology in its wider context. The aligning of biotechnology only with controversial issues also means that students may develop a distorted view of biotechnology rather than seeing it in its fuller context. This representation of technology in science only shows a relationship in terms of science to technology as application and this represents a view of technology as being applied science. It also tends to reflect a deterministic view of technology and in fact science for that matter.

DEFINING TECHNOLOGY IN RELATIONSHIP TO SCIENCE

With the introduction of technology into curricula and research there was much rhetoric internationally about the relationship between science and technology in the early 1990s. People use technology to expand their possibilities, to intervene in the world through the development of products, systems and environments. To do this, intellectual and practical resources are applied. Technology includes control, food, communications, structural, bio-related, materials, and creative design processes. From a research and development perspective, Gardner's (1994) review on science and technology had a significant influence. He argued that the relationship between science and technology could be seen in four ways:

- Technology as applied science;
- Science and technology as independent communities;
- Technology as giving rise to scientific understanding;
- Science and technology as equal and interacting communities.

Technology can be utilised in a variety of ways in science education, however in doing so it is important to have a clear concept both of the nature of science and the nature of technology. Too often in the past a limited view of technology in science has limited both the learning of science and the learning about technology. When technology is viewed as applied science it is assumed that there is a linear relationship in which science generates technology, and when this view is held the story of a technological development is projected through the science lens (Gardner, 1995). Gardner's description of technological fruits falling from scientific trees (Gardner, 1994) is a common representation of the scientific applications of bio-technological knowledge; for example, the utilisation of penicillin from Sir Alexander Fleming's discovery of the action of *Penicillium* moulds on bacteria. In fact such a relationship was far from linear and involved many people. Even though such a linear relationship can be discredited in any science/technology history, this simple “technology-as-applied science” relationship is still exploited in science education, since examples like the discovery of penicillin can provide fruitful illustrative examples of scientific processes. However the reality of modern science is that strategic research occurs in teams with a focus on the functional aspects of science and technology as it relates to human welfare, economic development, social progress and the quality of life. France (2007) explored biotechnology from Gardner’s framework in a thorough literature review of biotechnology education and its place in the curriculum. France concludes that biotechnology is a modern science which provides a context to show teachers how teams of scientists, technologists and social scientists work together.

INTEGRATION OF SCIENCE AND TECHNOLOGY

Venville, Wallace, Rennie, and Malone (2002) explored in detail notions of curriculum integration and what it might mean from both a theoretical and practical perspective. They explored the nature of integration and how it is represented in the school environment. They also examined why integration should be considered, and focused on student engagement and whether integration enhances learning in science. Venville et al. (2002) highlight several studies that show that an authentic curriculum, related to student needs and interests and to the world outside of school, results in increased participation and engagement and reduced alienation. In their paper they highlight competitions such as the *Science Talent Search* provide opportunities for the integration between science, mathematics and technology. They indicated that subjects such as science, when placed within an integrated curriculum that is based on content, is difficult to assess and relatively open to debate.

Venville et al. (2002) provide an example of integrated practice involving the use of technology-based projects. High School students worked on a technology project for 10 to 12 weeks that included technology, science and mathematics research components. An example of a technology project brief was to “design and produce an electric powered vehicle that can climb a steeper gradient on the standard test track than anyone else’s.” The technology aspect investigated traction options, materials and construction techniques, motor mounting options and power transmission systems. The science aspect investigated friction, gears and pulleys, torque and power transfer and how scientific trials influenced their choice of traction, gearing and drive options.

This is an area for further research but cognizance needs to be taken of the way science as a high status subject, and teachers’ and students’ perceptions of and understanding of the relationship between science and technology, will influence the outcomes in the classroom.

CONCLUSION

This chapter has considered ways in which technology has been included in science education research and development. A broad notion of technology was taken in terms of people using technology to expand their possibilities, to intervene in the world through the development of products, systems and environments. To do this, intellectual and practical resources are applied. Technology includes control, food, communications, structural, bio-related, materials, and creative design processes. From a research and development perspective this did not include the introduction of Information and Communication Technologies in science education.

The rationale for the introduction of technology in science has centred on an attempt to increase the relevance and authenticity of science to students. There is evidence that when this is introduced in an appropriate way that there is increased enjoyment and even improvement for some students in science achievement. Technology with science education has essentially been portrayed as applied science and limited aspects of technology have been included. Technology was essentially perceived as applied science and this influenced the way it was introduced to the classroom. The introduction of technology and also social aspects allowed for values and ethics to be introduced into the science classroom particularly in relation to biotechnology in biology classes. The introduction of technology into science classes has seen technology dominated by the science subculture. When technological applications were introduced in a themed approach rather than an add on then students were more likely to engage in science, enjoy it more and achieve both in science and technology. In the science curriculum technology has been essentially introduced as applied science although at the higher levels of the curriculum technology is seen as advancing science but the focus was on the direct links with science rather social or technological principles. The potential of technology to make a difference in the teaching and learning of science has probably not reached the potential we thought it might when we began exploring its introduction 25 years ago. The rise of technology education research as an area in its own right may have limited the further research into possible connections between science and technology.

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