STAV (Science Teachers' Association of Victoria) response to the Parliamentary Inquiry into Promotion of Maths and Science Education

While the terms of reference of the inquiry refer to promoting 'maths ***and*** science in Victorian education' (emphasis added throughout) we believe there are issues specific to the teaching of science which it would be helpful for the enquiry to consider, as well, of course, as larger issues that impact on both maths *and* science education, as well as other areas of the curriculum. This submission is primarily concerned with the promotion of science education in its broader context: the teaching and learning that occurs within schools and other educational institutions and the science education that students can experience in other ways

There are overlaps between the dot points stated in the terms of reference of this inquiry. When preparing this submission each dot point is considered separately for clarity.

We note that there have been a number of recent enquiries into aspects of science education. In particular the 2000 report prepared for DETYA by Denis Goodrum, Mark Hackling and Léonie Rennie titled *The Status and Quality of Teaching and Learning of Science in Australian Schools* remains a model of clarity as to the vision enunciated for science education, the research into the actual condition of science education and the steps required to bridge the gap. It is of great concern to us that, nearly 5 years later, so many of the problems these authors outlined remain and that so few of the steps for remediation have been taken. An extract from that report outlining an ideal picture of science education, the reality and recommendations for change, is attached as appendix 1.

1. **Determine which factors will support high quality teaching and learning of mathematics and science including teaching method and environment, subject knowledge, pedagogy, and teaching expertise**

1.1 Clarity of purpose(s) as to the reasons for teaching science.

We support the position taken by Goodrum et al. of the '*importance of science education in schools, particularly its fundamental role in developing scientific literacy'* and with the UK recommendation of Millar and Osborne in Beyond *2000: Science Education for the Futur*e, "that the primary and explicit aim of the 5-16 science curricula should be to provide a course which can enhance 'scientific literacy'." "Science" is a large domain, and without a clear notion about what is valued in science the approach to its teaching, including curriculum statements and preparation of resources, can become diffuse: bogged down in memorizing factual content or mastery of 'process'. The excitement of science that arises from its unifying explanatory power and the grandeur of its reach are all too easily lost. Many students currently say that science is boring. One of the underlying causes for this is that the purpose of teaching science is not clear in Victorian curriculum documents. The Curriculum and Standards Framework (CSF) lists 'outcomes' – what students should be able to do at the conclusion of a unit – but without any consideration of why they are important or how they link together (if indeed they do). What emerges can readily be dull and disconnected – the very antithesis of science! It is instructive to compare this situation with that of the American Association for the Advancement of Science's *Project 2061* in which the central text, *Science for all Americans*, makes a compelling case for science education focused on science literacy by setting out some of the unifying ideas in all areas of science and by examining the 'habits of minds' which cross all scientific disciplines. Outcome statements in the subsidiary document *Benchmarks for scientific literac*y are presented as guides to achieving the central purpose, not, as they stand by default in the CSF, as items of importance in their own right.

This remains a concern despite this state's new curriculum initiative: the Victorian Essential Learning Standards (VELs). There are features of VELs which have the potential for improved education, but the fundamental issues of purpose in science education remain unexamined. The booklet "Introducing the Victorian Essential Learning Standards" states that the CSF remains "an important curriculum resource to help teachers in writing teaching and learning programs" but the intent of that program, in science, is no more clearly envisioned than in the past. The removal of the CSF as a straightjacket, confining science education to the demonstrated achievement by students of a disparate collection of 'outcomes' is welcome; as too is the encouragement to take up social and ethical issues and to link science learning with that undertaken in other subject areas. However, lacking any articulate outline of what is central to science, of what distinguishes the scientific way of knowing from belief systems which are not self critical and self correcting, there is a danger of something going under the label 'science' becoming just another component in an 'integrated studies' program. We, on the other hand, see a solid grounding in science as the core of every student's general education.

We suggest that one reason this area is left unexamined is that it raises awkward issues. Science education for 'science literacy' may not fit readily with notions of science teaching as preparation for detailed studies in science. Both Fensham (1985) and Millar (1996) have pointed to the difficulty of the same curriculum serving both ends. In Victoria the effects of content driven VCE science subjects, designed as preparation for tertiary science studies, and taken by a small percentage of the cohort, will continue to percolate down to the compulsory years of schooling and dull the science learning of all students until this issue is explicitly examined.

1.2 The teacher as the most significant factor in affecting student learning.

The central role of the teacher in affecting the quality of students' education is almost universally accepted. This has led, quite reasonably, to a focus on factors which can improve the ways in which teachers carry out their role. On the other hand this examination has sometimes led to the unreasonable position that it is *only* factors intrinsic to the teacher which affect the teacher's performance of their task. Teachers don't work in a vacuum. The social, educational and physical setting in which education is conducted all have a profound influence on the manner in which each teacher works. The following are some of factors which affect the quality of an individual teacher's work:

- Nature of their pre-service teacher education.
- Extent and nature of in-service teacher education
- Curriculum setting in which they work
- Disciplinary and organisational setting in which they work
- Physical setting in which they work
- Time available for teaching science
- Quality and availability of resources in workplace
- Professional recognition, perceived status and self esteem
- Their subject knowledge in areas being taught
- Extent of pedagogical knowledge, especially that specific to areas being taught
- Extent of interest in, and knowledge of, cultural and social issues.

1.21 Pre-service teacher education.

There are great differences between courses at different institutions and there are substantially different issues in the pre-service training of Primary teachers and Secondary teachers. Some issues of concern are:

- The adequacy of the scientific knowledge attained by many Primary trainees prior to graduation. The situation remains as Goodrum (2000) reported:

  > …. The Discipline Review of Teacher Education in Mathematics and Science (Speedy, Fensham, & Annice, 1989) considered recommending that science not be taught at the primary school level because it was taught badly so often. Instead, the Review highlighted how little was being done by tertiary institutions to remedy a situation where preservice primary teachers lacked confidence in their science knowledge and skills and had negative views of teaching it. Although a survey in 1993 (Whithead, Symington, Mackay, & Vincent, 1993) concluded that gains had been made in terms of additional courses in science and/or science education, many of these were lost when financial cuts demanded less staff contact time in initial teacher education programs. Osborne and Simon (1996) have demonstrated the importance of science content knowledge as well as pedagogical knowledge for the pedagogical science content knowledge (Shulman, 1986) essential for good science teaching. Since 1997, primary teachers in England and Wales, where science is a core subject with English and mathematics, have been ***required to have a basic science qualification of 150 hours (Fensham, 1998). This is greater than that required for Australian primary teachers***.
  >
  > (page 35, emphasis added)

- The nature of selection and training of secondary science teachers to ensure depth and extent of scientific knowledge and adequacy of pedagogical preparation. Substantial numbers are entering Dip Ed training after other careers, some with education experience overseas, some with engineering qualifications or other non-science degrees. Secondary science education can benefit greatly from the diverse experiences these new teachers bring to the profession; but there is an accompanying need to ensure that quality is maintained. There can likewise be an issue of quality where trainees are certificated as qualified to teach science as an adjunct to another major teaching area.

  It is taken for granted that a basis for good training are courses which:
  - Are interesting and engaging,
  - Develop thinking scientifically rather than just knowing science.
  - Develop pedagogical knowledge, especially including that specific to the subject disciplines being studied.
  - Assist students to deal with the *practicalities* of the classroom; and the school.
  - Encourage students to work collaboratively and establish professional links,
  - Develop a wide range of assessment practices.
  - Encourage the teacher to educate "the whole child", not be exclusively concerned with a particular subject.
- Approaches to science education which emphasise science literacy, consideration of social and ethical matters and the establishment of links to other subject areas require science teachers with greater breadth of knowledge than was the basic threshold for the specialist science discipline teacher, while still requiring depth of understanding. A superficial acquaintance with science will not suffice.
- In these matters of quality of pre-service education, we note that the Victorian Institute of Teaching has as part of its charter the accreditation of these courses. Now that the VIT is established, it should be matter of priority to set up processes intended to ensure quality in pre-service science education courses, processes which are open and invite public participation.
- Present levels of funding for teacher education appear insufficient to provide the type of programs needed to ensure a supply of quality science teachers. Hence funding of pre-service teacher education is an urgent and essential issue.

1.22 Ongoing professional learning

Given the almost universal recognition of the teacher as the most significant determinant of the quality of education students receive, ongoing teacher professional learning can be categorised in several ways

by content	by intent	by mode
Science discipline knowledge & skills.	Development of individual as professional educator.	Individual workshop/seminar etc.
Pedagogical knowledge & skills.	Building a team approach ('whole school', 'whole faculty').	General conference.
Informing about changed program.		Extended focused program.
Acquisition of specific skills e.g. in ICT, or use of an instrument.		On-line.
		Out of school placement, 'sabbatical'.

Almost everything connected with science teaching is undergoing change. Progress is rapid in every discipline of science and many science teachers have difficulty maintaining current and emerging knowledge in their discipline. Science teachers within one school usually work collaboratively, but opportunities for contact with colleagues in other schools can be limited. In some situations, teachers receive professional learning of different kind mandated by the school, which does not always directly meet the needs of individual teachers. In- service education *cannot* be easily divided into worthwhile and valueless and we, while we support the conduct of within school PD, intended to build team approaches to teaching; this should not be at the expense of other forms of in-service professional development. Science teachers are generally good at deciding what is of value to them in enhancing their teaching. Activities which (a) help maintain current discipline knowledge and (b) which assist sharing of experience, and building professional networks beyond the immediate workplace are rated very highly by most science teachers.

Schemes which allow science teachers to work in industry, or in a research setting, can be very valuable. Details must be discussed to ensure that the teacher gains useful skills/knowledge and that it is not just a case of the teacher's existing skills being made use of in the placement. One year placements have been seen as less disruptive for both school and placement institution, but the cost has limited their number. Short term placements can be negotiated on a wider basis.

Other desirable actions to develop continuing in-service for science teachers

- Time for teachers' to prepare lessons, research and gather new knowledge and reflect on their own practice,
- Reduce the mandated 'face to face' time fraction
- Opportunities to engage in professional learning outside the school
- Funding for professional learning
- Additional support for improvement in quality of Primary Science teaching (to improve discipline knowledge).
- Encouraging teachers to be active researchers by providing funds and time release to do action research within their schools.

Schools and school systems should be encouraged to support science teacher participation in a wide range of in-service activities.

1.23 Curriculum setting

An aspect of this was discussed in 1.1 above. In a more general way the manner in which science teachers organise a program for their students is affected by whether the curriculum framework is prescriptive or allows a high degree of freedom to the teacher. We recognise that there is a tension here. The most exciting and stimulating school science programs are those conducted by enthusiastic and energetic teachers, often with a passion for a particular area. Not all teachers fit this mould. There is a need to maintain an acceptable level of instruction for all students and some degree of commonality in what is studied across schools and classes. The CSF emphasis on specific outcomes has tended to have a dulling effect on school science, with many science teachers lamenting that they feel inhibited by the requirement to cover these outcomes in the limited time available, from doing real science. The effects of the changes that will be brought about by introduction of the Victorian Essential Learning Standards are not clear and will need to be monitored.

1.24 Disciplinary and organisational setting

In common with other subject areas the structures in place within the school for coping with students who are disruptive or have special learning needs can have profound impact on the learning which takes place within the science classroom. Practical work is an integral part of good science teaching and it is here that the absence of an adequate school discipline structure can have a deleterious effect on student learning beyond that found in other subject areas. Practical activities in science classes are carried out to aid cognitive development rather than as a mode of personal expression and frequently safety make use of equipment and materials which have safety issues involved. Despite the best intentions of the science teacher their program will default to the less engaging “talk & chalk” mode when there is lack of assistance within the school in dealing with troubled students.

We believe that reducing class sizes and supporting teachers with providing laboratory assistance will improve the situation. This support provides teachers the capacity to deal with special needs of these students and maintain the safety aspects of practical work.

1.25 Physical setting

Ideally all science classes will be taught in specialist science classrooms. This does not happen, but the vast majority of classes get access to a ‘science room’ for some time each week. Almost all of these science rooms are old and built without thought to the use of ICT in education. Schools building new science facilities obtain ideas from colleagues and from overseas sources – local guidelines don’t exist. New facilities are being built which have basic deficiencies. Quality science teaching makes use of direct instruction, group discussion, practical activities and a variety of ICT uses. A school science room should enable all of these. A particular concern is to do with ICT use. While there has been a great deal of talk about ICT use in Victorian education and considerable money spent (e.g. teacher notebook program), there are some quite specific details of existing infrastructure which inhibit ICT use in science. ICT resources must be at the student desktop, not in an IT laboratory separate from the science classroom. The teacher’s notebook is of limited use *within* class if there is no data projector to enable it to be used in teaching the class. Visiting science teachers from South Korea, in 2003, and from Singapore, in 2004, have expressed great surprise at the poor provision of ICT facilities in science classrooms in Victoria, and at the generally antiquated nature of so many of the rooms they visited.

There is an urgent need to upgrade the standard of facilities used for teaching science in Victorian schools.

Time spent on science.

What can be achieved by the science teacher is affected by the time available for teaching science. Two immediate concerns here, regarding the current situation in Victoria, are that
(a) comprehensive current data is not available (b) guidelines don't exist.

Goodrum (2000, page 131) reports that the time per week spent studying science in Australian secondary schools varied across states with average figures from a high of 240 minutes to a low of 150 minutes. Victoria is at the lower end of this range. There is moreover considerable variation from school to school, and anecdotal evidence suggests a tendency for a recent reduction in time for science during years 7 to 10, accompanied by a trend to make science an elective subject at year 10 (and sometimes at year 9) rather than part of the core curriculum.

This is an obvious concern, for as Goodrum notes:

> The relationship between learning achievement and time on learning is well accepted. If the quality of science learning is to be improved, it is obvious the amount of time devoted to this task needs to be increased.

(p 207)

Within Primary schools the average time spent on science is much smaller, and the variation is even greater. Again Goodrum provides national average and comment pertinent to this state:

> Teachers, on average, indicated that science was taught 59 minutes per week, however, there is wide variation between teachers and between schools. Despite parents' ranking of science as the third most important subject in the primary school curriculum following English and mathematics (ASTEC, 1997), many teachers revealed that science has a low priority in the overcrowded curriculum. Australian focus group participants explained how the current focus on literacy had put increasing pressure on other subjects, including science.

(p 189)

The time spent on science education in Victoria should be increased and reliable, current, data maintained.

1.26 Quality and availability of resources

Science teachers develop their own teaching resources as well as collecting diverse existing materials and making use of purpose designed resources (texts, videos, software etc) produced by others, especially educational publishers and other commercial providers. The quality of all of this is variable and evaluation of the materials both prior to use and in review is commonly ad hoc. Teachers are able to revise and improve the quality of the material they originate, and there is evidence that this occurs, subject to limitations of time and other factors. It is difficult to see efficient ways of altering this. A great deal of the material used in teaching science is of commercial origin. While these is no desire to move to a system of mandated texts (nor any reason to believe that such a system would improve quality) there are grounds for thinking that improvement could be made and there some models to follow in doing so. Publishers have noted the dilution of available resources in catering for eight educational jurisdictions within Australia rather than one national market. This is particularly absurd in the field of science where the bulk of the content is universal rather than national, let alone local in scope. Goodrum (2000) comments:

> Developing quality curriculum resources and professional development programs is an expensive process. It seems obvious that by collaborating and combining limited funds, better quality resources can be produced. By working on a national basis one can draw upon the best expertise in the country to develop resources that are sufficiently flexible to support the curriculum frameworks in different jurisdictions. National resources do not require a common, national curriculum for effective implementation. Electronic delivery would facilitate the flexibility of implementation of these resources. Each education jurisdiction should reflect on their mandated requirements and allow teachers the flexibility to implement learning experiences based on the needs of their students and school situations.

(p 211)

In the USA, as part of American Association for the Advancement of Science's long term plan to improve the quality of school science education (Project 2061), a scheme has been developed to assess available texts against objective criteria based on the purpose of science education and research findings about effective teaching methods. Evaluation of ten commonly used texts, each superficially attractive, resulted in only one being given a satisfactory evaluation. Because of their widespread use textbooks have considerable impact on the quality of learning in science. Objective evaluation of texts, on the model developed by the AAAS, would assist teachers in textbook selection and would lead to long term improvement in texts.

There has been some systemic involvement in producing electronic resources for science teaching through projects such as PRISM in Victoria and the science component of the national Learning Federation project. We note that there is a very large resource of electronic materials freely available via the World Wide Web, but that they are under utilised due in large part to teachers' lack of knowledge about their availability and nature. There may be some point in developing new materials to supplement what exists, but a good initial use of money would be would be to review existing WWW material and make the results available to teachers. PRISM and Learning Federation materials should be subject to critical review to guide any future development that might be undertaken.

1.27 Professional recognition, status and self esteem

Teachers, like other workers, give of their best when they feel their work is valued and there is recognition of their professional status.

Programs such as the Prime Minister's Prize for Excellence in Science Teaching are commendable, but their 'big' nature deters many teachers from considering themselves as potential candidates for such awards. It would be desirable to develop a range of ways of giving public recognition to the work of science teachers.

Perhaps more significant is the development of measures of achievement that have tangible significance for science teachers within schools.

Alongside the limitation of entry into the profession to suitably qualified persons via The Victorian Institute of Teaching, there should be recognition of experienced science educators. The Australian Science Teacher's Association has developed a set of Professional Standards for Highly Accomplished Teachers of Science, and a program based on these should be developed which recognises such accomplishment.

2. Examine national and international trends, and report on innovative initiatives, that promote the teaching and learning of Maths and Science

Public awareness and appreciation of science teaching as a profession has to be promoted. Organising campaigns to raise awareness among the general community about critical social importance of science teaching is essential. Programmes which raise the awareness of responsibilities and rewards of science teaching among secondary students should be developed and allowing secondary students to do peer tutoring to younger students may help them to make informed judgements about their interest as well as suitability for teaching.

Innovative initiatives in promoting science teaching

- Establishing more Awards for teachers to recognise their work.
- Media recognition and promotion of existing awards (Prim Minister's Award, BHP award, Herald Sun award, NQSA, ect…,).
- More rewards and remunerations.
- Projects with bodies like CSIRO so groups of teachers can be recognised and work alongside students and the achievements be known.
- Certification for accomplished and high quality teaching.

3. Determine how best practice in teaching of Maths and Science can be shared among schools and other education communities and identify other opportunities for cross government action

There is a vast amount of *best practice* out there that teachers do not currently share due to many reasons. As practitioners we can benefit with ideas from others. Sometimes with a little bit of customising and tweaking, apply in a way that is meaningful to our teaching. Developing a culture of sharing and mutual learning will certainly improve the quality of teaching science. It is important to create and organise opportunities to share as well as invest more resources in releasing teachers to participate in such sharing activities. The encouragement should come from school leaders and all stake holders for this. Some points when considering action are given below.

- Developing a program to facilitate visits or short exchanges to other schools by highly competent and committed teachers to act as agents of change.
- Developing and supporting a cadre of science teachers, able to support, mentor and guide other teachers.
- Promoting Federal initiatives such as NQSF and Think.com at a state level.
- Supporting STAV to run state wide initiative such as Science Talent Search and Science Drama.
- Organise specialist excursions/camps/initiatives for students with a keen interest in science to accelerate the learning and enthusiasm (this could be done through subject associations and other research institutions).
- Supporting subjects associations to organise conferences for teachers to share and learn with other teachers.
- Support subject associations to develop teacher networks for teachers to get mutual support.
- Support subject associations to develop online communities of common practice (COPs).
- Supporting subject associations for journal publications.
- State could negotiate and provide electronic access to international and national journals such as *Science News, Physics Education, Scholl Science Review.*
- Support subject associations to maintain an area in their web sites for teachers to share information on the internet including their projects, classroom activities, etc.

4. **Determine how new business, industry and research applications of mathematics and science can be integrated into schools and learning communities.**

- Release teachers to work in the industries with emerging new sciences to get hands-on experience on new research applications and encouraging them to share the experience with the wider teaching community.
- Through subject associations develop programs to raise awareness of new and emerging scientific applications.
- Build a climate of enterprise for students to see science not just as a source of intellectual satisfaction but providing opportunities for entrepreneurs.
- Support to integrate new sciences into secondary curriculum and also developing teaching materials and tools for classroom teachers' use.

5. **Examine the potential for greater cross – sectoral links between industry, tertiary and training institutions and schools in the promotion of mathematics and Science Education**

- Creation of a state network of local and regional science clusters linking schools and teachers' with STAV, science organisations, tertiary institutions and industry.
- Encouraging and funding collaborative action research projects with schools, industry and tertiary institutions. Government funding of research initiatives should not be allocated solely to government schools but to independent schools as well.
- Providing student awareness programs within industries about practical applications of sciences.

6. **Examine gender issues in the teaching and learning of mathematics and science education.**

Contemporary research indicates that female secondary students often feel negative or ambivalent about their study of physical science. Workplace participation figures also indicate a relatively low participation rate of females in physical science related professions.

There are many possible explanations that can be identified for the gender disparity in the participation of science and maths. Researchers have suggested many variables including biological, sociological, attitudinal, institutional and affective (Keane: 2000 and Martindale: 1995). But none of these variables fully explain the visible gender imbalance.

Others have suggested three other factors of curriculum, pedagogy and stereotyping as further reasons for this imbalance. Suggested actions are listed below.

6.1 Curriculum

- Continuous efforts should be made to acknowledge and include the educational needs and experience of girls equally with those of boys in all science curricula.
- Both content and language should be female friendly in physical sciences.
- Assessments also should consider more flexible approaches.

6.2 Pedagogy

- Encouraging contextual approaches.
- Encouraging cooperative learning.
- Introducing multiple intelligences.
- Introducing brain compatible learning.
- Teachers need professional learning to understand the different styles needed to teach boys and girls.

6.3 Stereotypes

- Develop and fund ***gender equity programs*** in science and mathematics in schools.
- Raise awareness among teachers' and parents about the disparity.
- Recognise and begin to change long standing gender imbalances.
- Provide more opportunities and scholarships for girls with the intention of developing role models for girls.

Further to this there is an opposite trend reported in biology/psychology areas. Acknowledging there are many factors the following has been identified.

- Gender imbalance of teachers in these fields.
- Lack of male secondary teachers.

In general the profile of Australia's teachers are gender bias towards females. This is more visible in primary schools. However, at secondary levels, male teachers are more represented in learning areas of science, mathematics and technology. Teacher workforce planning should consider these statistics to counter the imbalance in all areas.

7. Consider ways of promoting greater interest by suitably qualified people to undertake mathematics and/ or science teaching careers.

The research predictions suggest that supply of teachers would be only 70% of the demand by 2005 (Australia's Teachers: Australia's Future, 2003). To attract suitably qualified people into this profession a series of strategies should implemented with coordinated action by all stakeholders. The high quality teacher education, attractive employment conditions, professional standards and ongoing professional learning opportunities should be included in the strategy. The following are some actions for consideration.

7.1 Better Rewards and Conditions

- Career paths.
- Improved remuneration.
- Increased resources.
- Changed (reduced) workloads, inbuilt time for professional learning, reflection of practice, establishing initiatives, etc and offload other administrative type tasks such as bus duty, exam supervision.
- Administrative assistance for teachers so they can focus on their teaching
- Reallocation of responsibilities and duties.
- Improved professional standing in the community.
- Reduced class sizes.
- Evaluation of classroom curriculum materials.

7.2 Better and flexible Training/Professional Learning Opportunities

- High quality teacher education programs.
- Sufficient teacher education places, particularly in Science.
- Teachers of science should not pay more HECS than others or HECS free courses.
- Develop collaboration with other faculties (Science, Engineering, Agriculture) to offer elective teacher education units in non-teacher education programs.
- Provide paid internships, (training) for science teachers' (like in forces).

- Greater and encouraged opportunities for science professionals to get teaching qualifications.
- More programs available, for teachers to return to university to update skills – (perhaps even compulsory).
- Engagement with real science: speakers and excursions – need to make it easier for teachers to do this.

7.3 Better In-service training

- Compulsory post-graduate study.
- Scholarships and other incentives be offered to undertake studies to advance their scientific knowledge.
- HECS free post graduate opportunities.
- Financial assistance modelled on the scheme used in the military forces be provided to trial and develop innovative approaches.
- Financial assistance (like in corporate sector) to participate in conferences to share and develop professionally.

Appendix 1

A copy of this report is located at http://www.detya.gov.au/schools/publications/ index.htm

References.

AAAS Project 2061 *Middle Grades Science Textbooks Evaluation* http://www.project2061.org//publications/articles/textbook/mgsci/charts.htm

American Association for the Advancement of Science. (1990). *Science for all Americans.* New York, Oxford University Press. http://www.project2061.org//tools/sfaaol/sfaatoc.htm

American Association for the Advancement of Science. (1993). *Science for all Americans: Benchmarks for scientific literac*y. New York, Oxford University Press. http://www.project2061.org/tools/benchol/bolframe.htm

ASTA, *National Professional Standards for Highly Accomplished Teachers of Science* http://www.asta.edu.au/membership/benefits/recognition/profstds

DEST (2003). *Australia's Teachers: Australia's Future – Advancing innovation, Science, Technology and Mathematics,* The Report of the Committee for the Review of Teaching and Teacher Education

Fensham, P. J. (1985). *Science for all: A reflective essay*. Journal of Curriculum Studies, 17*,* 415-435.

Fensham, P. J. (1997). *School science and its problems with scientific literacy*. In R. Levinson & J. Thomas (Eds.), *Science today: Problem or crisis?* London: Routledge.

Goodrum, D., Hackling, M. & Rennie, L. (2000) *The Status and Quality of Teaching and Learning of Science in Australian Schools*. Canberra: Department of Education, Training and Youth Affairs http://www.detya.gov.au/schools/publications/ index.htm

Millar, R. (1996). *Towards a science curriculum for public understanding*. SchoolScience Review, 77(280), 7-18.

Millar, R., & Osborne, J. (1998). *Beyond 2000: Science education for the future* (The report of a seminar series funded by the Nuffield Foundation). London: King's College London, School of Education. http://www.kcl.ac.uk/depsta/education/be2000/index.html

PRISM (Practical Resources and Interactive Science Materials) http://online.curriculum.edu.au/dev/

The Learning Federation, science learning objects http://www.thelearningfederation.edu.au/tlf2/showMe.asp?nodeID=74

Victorian Curriculum and Assessment Authority. *Curriculum and Standards Framework*. Melbourne. http://csf.vcaa.vic.edu.au/sc/kssc.htm

Victorian Curriculum and Assessment Authority (2004) *Introducing the Victorian Essential Learning Standards*. Melbourne. http://vels.vcaa.vic.edu.au/index.html