BOSTES
BOARD OF STUDIES
TEACHING &
EDUCATIONAL
STANDARDS NSW

NSW SENIOR SECONDARY REVIEW & EVALUATION: SCIENCE

REFERENCE REPORT

1. Historical overview

Courses

In response to the NSW Government's White Paper *Securing their Future*, the Board of Studies, Teaching and Educational Standards NSW (BOSTES) undertook a comprehensive review of the Higher School Certificate (HSC) in the late 1990s. The White Paper endorsed the development of a 2-unit curriculum model across all HSC subjects and called for a clear definition in each course of the content (knowledge, understanding and skills) students are expected to learn. The new senior secondary Science syllabuses were approved in June 1999, implemented for the Preliminary cohort in 2000 and first examined for the HSC in 2001.

There has been no significant change made to the content of the secondary Science suite of syllabuses since amended syllabuses were published in 2002.

In recognition of the principle that the post-compulsory years of schooling should cater for students who choose to participate, eight Stage 6 Life Skills courses were also developed in 1999, including one for Science. These courses extended the curriculum and reporting arrangements that were established in Stage 5 to HSC students with intellectual disabilities. The Science Life Skills course provides a curriculum option for students unable to access the outcomes and content of the regular Science syllabuses. The Science Life Skills course has Board Developed status and can be used to meet the requirements for the award of the HSC without an external examination. Minor amendments were made to the guidelines and assessment advice for the Science Life Skills course in 2007.

Assessment and examination

In 2008, the BOSTES undertook a major review of HSC assessment, and changes to examination specifications and school assessment requirements were implemented for HSC courses from 2010. Assessment components and some examination specifications were adjusted to more closely align with course outcomes. These changes are outlined below:

- further guidance provided on responses to various types of examination questions, including an indicative length for all extended written responses and a due emphasis on quality, organisation, relevance and structure for all responses
- changing the mark value of Section I responses. Section I Part A was increased from 15 marks to 20 marks and the mark value of the short-answer questions found in Section I Part B was decreased from 60 marks to 55 marks
- changes to the senior secondary Science course assessment components and weightings to reflect a ratio of Knowledge 40%, Investigating 30% and Problem-Solving 30%
- amendments to some marking guidelines and rubrics to support changes to assessment and examination specifications
- the implementation of minor course-specific changes
- a focus on objectives and groups of outcomes for school assessment programs
- some minor wording adjustments to the internal assessment requirements of all senior secondary Science courses.

2. Course requirements

Biology, Chemistry, Earth and Environmental Science, Physics and Senior Science

The Stage 6 HSC syllabuses (excluding Science Life Skills) comprise a Preliminary course and an HSC course. The Preliminary and HSC courses are organised into a number of modules.

The Preliminary course consists of four core modules containing content to be covered in 120 indicative hours.

The HSC course consists of three core modules and a number of options[1]. The core content covers 90 indicative hours with each option covering 30 indicative hours. Students are required to cover one of the options.

Practical experiences are an essential component of both the current Preliminary and HSC courses. Students are required to complete 80 indicative hours of practical/field work during both the Preliminary and HSC courses with no less than 35 indicative hours of practical experiences in the HSC course. Practical experiences must include at least one open-ended investigation integrating skill and knowledge outcomes in both the Preliminary and HSC courses but may also include ICT activity.

Science Life Skills

Students enrolling in a Stage 6 Life Skills course will usually have completed Years 7–10 Life Skills outcomes and content in one or more courses. The Life Skills course provides greater flexibility for teachers to select outcomes and content that meet students' individual learning needs, strengths, goals and interests.

The Science Life Skills course is designed for the small percentage of students, particularly those with an intellectual disability, for whom adjustments to teaching, learning and assessment are not sufficient to access some or all of the regular Science outcomes.

The senior secondary Science Life Skills course contains six modules to be studied over 120 hours in each of the Preliminary and HSC years.

[1] All senior secondary Science syllabuses consist of five options in the HSC course, with the exception of Earth and Environmental Science, which has four.

The following table provides an overview of the structure and assessment experiences provided within each of the senior secondary Science courses.

Table 1: Stage 6 Science course requirements

Course	Structure		Assessment		
	Core	Options	School-based	HSC written examination	Submitted work
Biology	7	1	Y	Y	N
Chemistry	7	1	Y	Y	N
Earth and Environmental Science	7	1	Y	Y	N
Physics	7	1	Y	Y	N
Senior Science	7	1	Y	Y	N
Science Life Skills	–	6	Y	N	N

3. Candidature

The following tables summarise candidature in each course within the Science key learning area from 2009–2013.

Table 2: HSC candidature by Science course 2009–2013

Course	2009			2010			2011			2012			2013		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
Biology	5810	9498	**15308**	6135	9714	**15849**	6466	10238	**16704**	6411	10159	**16570**	6539	10313	**16852**
Chemistry	5443	4598	**10041**	5643	4687	**10330**	6050	4915	**10965**	5989	4849	**10838**	6025	5007	**11032**
Earth and Environmental Science	732	661	**1393**	741	708	**1449**	774	699	**1473**	808	689	**1497**	703	696	**1399**
Physics	6759	2265	**9024**	7256	2103	**9359**	7247	2135	**9382**	7349	2120	**9469**	7435	2127	**9562**
Senior Science	2605	2197	**4802**	2704	2197	**4901**	2831	2546	**5377**	2901	2334	**5235**	2908	2533	**5441**
Science Life Skills	256	175	**431**	263	156	**419**	308	162	**470**	299	151	**450**	298	185	**483**

M = Male *F* = Female *T* = Total

Table 3: Preliminary candidature by Science course 2009–2013

Course	2009			2010			2011			2012			2013		
	M	F	T	M	F	T	M	F	T	M	F	T	M	F	T
Biology	8219	12751	**20970**	8848	13492	**22340**	8719	13240	**21959**	8918	13760	**22678**	9024	13732	**22756**
Chemistry	7939	6933	**14872**	8535	7279	**15814**	8387	7092	**15479**	8455	7248	**15703**	8830	7393	**16223**
Earth and Environmental Science	1055	1016	**2071**	1116	1024	**2140**	1151	992	**2143**	1037	1001	**2038**	1152	1007	**2159**
Physics	9443	3027	**12470**	9425	3048	**12473**	9605	3045	**12650**	9745	3062	**12807**	10009	2998	**13007**
Senior Science	2267	1565	**3832**	2439	1862	**4301**	2454	1654	**4108**	2325	1756	**4081**	2570	2095	**4665**
Science Life Skills	301	190	**491**	395	202	**597**	386	196	**582**	412	232	**644**	586	218	**804**

M = Male *F* = Female *T* = Total

Table 4: Number of students by system for Science courses 2009–2013

Course	2009			2010			2011			2012			2013		
	Gov	Ind	Syst	Gov	Ind	Syst	Gov	Ind	Syst	Gov	Ind	Syst	Gov	Ind	Syst
Biology	8423	3968	2655	8811	4015	2788	9371	4151	2955	9373	4292	2700	9568	4141	2963
Chemistry	5729	2866	1342	5969	2930	1324	6482	3027	1368	6445	3000	1299	6471	3039	1458
Earth and Environmental Science	716	410	241	825	319	279	799	323	299	866	365	226	803	312	267
Physics	5135	2582	1216	5408	2628	1236	5426	2616	1267	5584	2606	1207	5700	2577	1234
Senior Science	373	719	980	3174	611	981	3512	702	1074	3247	731	1160	3424	788	1122
Science Life Skills	3013	46	12	384	18	17	435	26	9	401	31	18	429	35	19

Gov = Government schools *Ind* = Independent schools *Syst* = Systemic schools

Table 5: Number of students by area for Science courses 2009–2013

Course	2009			2010			2011			2012			2013		
	Met	Reg	O'seas	Met	Reg	O'seas	Met	Reg	O'seas	Met	Reg	O'seas	Met	Reg	O'seas
Biology	9345	5790	173	9727	5967	155	10170	6422	112	10104	6337	129	10583	6155	114
Chemistry	6863	2981	197	7228	2915	187	7645	3164	156	7650	3052	136	7764	3137	131
Earth and Environmental Science	737	656	–	766	683	–	809	664	–	783	714	–	804	595	–
Physics	6092	2750	182	6336	2866	157	6506	2739	137	6539	2808	122	6619	2840	103
Senior Science	2690	2112	–	2654	2247	–	2969	2404	4	2868	2364	3	2967	2470	4
Science Life Skills	207	224	–	222	197	–	243	227	–	260	190	–	249	234	–

Met = Schools in the Sydney metropolitan region *Reg* = Schools in country areas of NSW *O'seas* = Schools located outside Australia

Table 6: Apparent retention of candidates in Science HSC courses 2009–2013

Course	2008–09			2009–10			2010–11			2011–12			2012–13		
	Prelim	HSC	% Ret	Prelim	HSC	% Ret	Prelim	HSC	% Ret	Prelim	HSC	% Ret	Prelim	HSC	% Ret
Biology	20055	15308	76	20970	15849	76	22340	16704	75	21959	16570	75	22678	16852	74
Chemistry	14405	10041	70	14872	10330	69	15814	10965	69	15479	10838	70	15703	11032	70
Earth and Environmental Science	2006	1393	69	2071	1449	70	2140	1473	69	2143	1497	70	2038	1399	69
Physics	11938	9024	76	12470	9359	75	12473	9382	75	12650	9469	75	12807	9562	75
Senior Science*	3901	4802	123	3832	4901	128	4301	5377	125	4108	5235	127	4081	5441	133
Science Life Skills	529	431	81	491	419	85	597	470	79	582	450	77	644	483	75

*The HSC Senior Science course can be entered or added to a student's HSC pattern of study by students who have successfully completed any Preliminary Science course. This provides an explanation why Senior Science has an apparent retention rate of above 100%. The actual retention rate for Senior Science is the number of students who commenced the Preliminary Senior Science course and subsequently completed the HSC Senior Science course.

The senior secondary Science course candidature retention rate data reflects a significant drop in retention in the Science courses in comparison with the total Preliminary to HSC candidature retention rate of 87%.

Table 7: Apparent retention rate of all HSC Candidates and candidates in Science HSC courses (2012–2013)

	2012 Preliminary Candidature	2013 HSC Candidature	Apparent Retention Rate
Total HSC Candidature	85877	74277	**86%**
Biology	22678	16852	74%
Chemistry	15703	11032	70%
Earth and Environmental Science	2038	1399	69%
Physics	12807	9562	75%
Senior Science	4081	5441	133% (70% actual retention[2])
Science Life Skills	644	483	75%

[2] In 2012 there were 4081 students who completed Preliminary Senior Science and of these 2870 completed HSC Senior Science. From this, the actual retention rate for the HSC Senior Science course from 2012 to 2013 can be calculated as 70%.

4. NSW consultation on the senior secondary Australian curriculum

The BOSTES conducted consultation on the draft senior secondary Australian curriculum for Science during June–July 2012. The NSW consultation consisted of metropolitan and regional face-to-face focus group meetings with teachers and key stakeholders, as well as an online survey. A range of submissions were received from the NSW education sectors, professional associations and individuals. The *Senior Secondary Science Consultation Report* can be accessed through the BOSTES website at <http://www.boardofstudies.nsw.edu.au/australian-curriculum/11-12-eng-maths-sci-hist.html>.

Following consultation, the BOSTES provided advice to the Australian Curriculum, Assessment and Reporting Authority (ACARA) about the senior secondary Australian curriculum for Science, including:

- The language of the rationales should be revised to take into account the broader audience and the clarity of the wording of the aims should be reviewed.
- The intent of the rationale and the aims should be consistent with and supported by the subject structure and content descriptions.
- The units should provide a conceptual framework through the sequential organisation of key concepts/ideas necessary to develop the core understanding and skills appropriate for the range of students.
- The amount of content should be significantly reduced to that which is achievable in the time available to schools.
- The relationship between the strand content should be clear and the amount of Science Understanding (SU) and Science as a Human Endeavour (SHE) content should be reduced to provide adequate time for students to learn through a Science inquiry approach that will develop deep understanding.
- There should be a major review of all content descriptions to ensure clarity, scientific accuracy and an appropriate level of cognitive demand for the range of senior secondary students.
- The content descriptions in the SU and SHE strands should be reduced to broad statements of the key concepts/ideas that are appropriate for the range of students.
- The general capabilities and cross-curriculum content should be clearly identifiable and should be able to be authentically addressed in the time available to schools in senior years.

The structure and organisation of the Australian curriculum represents the largest challenge for integration into NSW Science courses. The systems-based approach requires very detailed study of components of a system leaving little time for more contextualised learning. The separate Science as a Human Endeavour strand disguises the heavy content requirement and associated high level of demand. Content descriptions are too broad and multi-faceted to be useful organisers for describing what students should know and do. There is considerable revision and rewording required to clarify what is expected.

The courses generally relate to students who aspire to undertake Science courses at university. They overlook the needs of students who wish to study senior Science courses to support other tertiary and vocational pathways.

The presentation of skills content is overly generic. More detailed description is required and there is insufficient time for a scientific inquiry base to teaching and learning. There is no prescribed requirement for an extended scientific investigation and insufficient space for this, given the amount of Scientific Understanding and Science as a Human Endeavour content to be covered.

Conceptually the demand is less than current NSW syllabuses but the volume of content remains too much to study in depth in the allocated time frame. The extent of content in the Australian curriculum for Science supports a teacher-centred, content- driven, topic-by-topic pedagogical approach to teaching rather than a 21st century approach including project-based inquiry learning.

In revising the senior secondary NSW curriculum for Science, the advice to ACARA will be considered.

5. Literature review

5.1 ACARA literature review

In developing the senior secondary Australian curriculum for Science, the National Curriculum Board (now ACARA) released the *National Science Curriculum: Framing Paper* (2008) which drew on work contained in the two-volume *Australian School Science Education National Action Plan 2008–2012* (Goodrum & Rennie 2007. This report provided an up-to-date synthesis of national and international research on school science education. ACARA also reviewed national and international Science curriculums, including that of the United Kingdom, Singapore, Ontario and New Zealand. Another report that was valuable in preparing the framing paper was *Re-imagining Science Education: Engaging students in science for Australia's future* (Tytler 2007). The genesis for this report was a national conference titled 'Boosting Science Learning: What will it take?' held in Canberra in 2006. The conference, sponsored by the Australian Council for Educational Research, brought together many stakeholders from the different science education interest areas with the focus on improving school Science learning.

ACARA's work has been further guided by some key national and international references, including:

- International Baccalaureate Diploma subjects in the Sciences
- A Framework for K–12 Science Education: Practices, Crosscutting Concepts and Core Ideas (Committee on Conceptual Framework for the New K–12 Science Education Standards; National Research Council, USA, 2012).
- The Status and Quality of Year 11 and 12 Science in Australian Schools (Goodrum et al, Australian Academy of Science, 2012).

In addition, as a part of ACARA's curriculum development process the senior secondary Australian curriculum subjects were reviewed by eminent overseas experts and international curriculum authorities.

5.2 NSW literature review

In 1997 a Science Symposium was held at St Mary's High School to lay the foundation for the development of the senior secondary Science syllabuses for the new HSC. Below are key findings which influenced that development and which remain relevant to syllabus development. Further findings are available in Appendix 1.

Key findings from the 1997 Science Symposium:

- Inquiry and investigation should be central to the study of Science; for example, biology is the process of finding out about living things.
- The practical nature of the courses was to be emphasised and students should be required to complete a major project.
- There is the need for specified content but an increased emphasis on higher order skills is required.
- Assessment practices require review to ensure a range of assessment experiences.
- The nature and emphasis of the external examinations need to be considered.
- The possibility of a common core plus module, including project-based learning, is to be considered.
- Core learning is to be based on processes/skills, values and attitudes rather than knowledge alone.

There is currently much debate about developing opportunities to allow students to access multidisciplinary project-based learning opportunities in Science. This notion was also raised at the 1997 Science Symposium where stakeholders supported the provision of a creative and flexible learning structure via a range of pathways, allowing students to have more control over their learning.

A recent study published in the National Academy of Sciences, *Active learning increases student performance in science, engineering, and mathematics* (Freeman et al 2013), compares failure rates of students whose courses used some form of active learning methods against students in traditional, lecture-based courses. The study was a meta-analysis of 225 studies of undergraduate education in the Science, Technology, Engineering and Mathematics (STEM) disciplines. The study indicates that engaging students actively by having them participate in learning by doing, rather than passively observing and listening, yields better outcomes for the student.
Research also indicates that to increase student motivation, a focus is needed to provide learning experiences that are related to the individual, where competence can be demonstrated and autonomy encouraged. This research supports the ideas of student choice and related opportunities for students to engage in self-selected research. This is the basis of the Self-determination theory, explained fully in *Self-determination theory and the facilitation of intrinsic motivation, social development, and wellbeing,* Ryan & Deci (2000).

5.3 Recent significant developments and practices in Science

An increasing focus exists on the relevance of Science, Technology, Engineering and Mathematics (STEM) education as a means to lift productivity and economic growth and secure Australia's future in a global context of continual change. This is evidenced in the July 2013 Australian Chief Scientist, Professor Ian Chubb's, position paper *Science, Technology, Engineering and Mathematics (STEM) in the National Interest: A Strategic Approach*, released in July 2013. This paper envisaged that by 2025 STEM will have equal status to citizenship and literacy in Australian schools' culture and curriculum (Chubb 2013).

Curriculums, it is being argued, should provide opportunities for students to become STEM literate and to obtain the knowledge, understanding and skills to participate in a STEM workforce as well as become proficient STEM practitioners. Developments in senior secondary Science syllabuses should consider the incorporation of practical skills, the inclusion of learning that is inquiry-based, fostering critical thinking, creativity and reflection, gender equity in the acquisition of STEM concepts and skills, and the knowledge and skills required to participate in a STEM workforce in the 21st century.

Pedagogical practices in Science are experiencing significant challenges. There is a shift away from content dense curriculums towards a less prescriptive structure that has been adopted and applauded, particularly across the tertiary sector (Crowther, P & Savage, S 2008 and Oliver, B 2013). The Australian Council for Educational Research (ACER) calls for a significant re-imagining of Science education as opposed to a notion of the mere refinement of curriculum and assessment (Tytler, R 2007, p 1–5).

Newly developed curriculum is being driven by the needs of students, and learning opportunities are being challenged by technology to create opportunities for students to follow their own learning pathways. This is supported by a reduction in passive, lecture-style delivery of content. Blended learning programs are being integrated extensively in schools and the higher education sector, transforming the traditional content acquisition cycle for the learner (Woltering, V et al 2009; Clark, I & James, P 2005; Lovell, K, Vignare, K 2009 and Covill, D, Patel, B & Gill, D 2013).

Through seamless and intentional integration of online resources[3] – often incorporating problem-based learning– (Eberlein, T et al 2008 and Inel, D & Balim, A 2010) students are learning to learn independently and further develop critical analysis skills. This shift from teacher-centred to student-centred learning has also been a vehicle for promoting an inquiry oriented approach to learning (Spronken-Smith, R and Walker, R 2010, Casotti, G et al 2008 and Cobern, W et al 2010). Students work independently or collaboratively on open projects, learning to identify the questions to ask and the approach for investigating them. Another element of the student-centred approach is the use of reflective thinking and writing in Science where students are encouraged to reflect on learning opportunities (Towndrow, P et al 2008, Toth, E et al 2002). This requires students to describe, interpret, evaluate and apply their knowledge, understanding and skills.

Assessment practices are also undergoing significant renewal in Science. The use of summative examinations as the primary assessment tool is being widely questioned in the higher education sector. The concept of authentic assessment (Kearney, S 2013), whereby students are assessed on skills that mimic professional practice has gained significant support. This has been accompanied by the use of self and peer assessment (Wai-Yin, P et al 2009), allowing students to refine reflective skills.

Currently, the NSW senior secondary curriculum includes single Science courses in the traditional strands of Science: Biology, Chemistry, Physics and Earth and Environmental Science. Given the pace of development of the information age and the fact that traditional pathways in the study of Science have multiplied and become more multidisciplinary, continuing support for this single strand structure is questionable.

[3] Massive Open Online Courses (MOOCs) are another development in the sector, but it is recognised that MOOCs typically fail to provide authentic, hands-on laboratory opportunities for Science students. This is a significant drawback for a solely online delivery of learning in Science.

There is an emerging need for a contemporary, scalable senior secondary Science curriculum that adopts a flexible approach to its delivery, has a reduction in the content prescribed to allow for authentic project or research-based learning, and feeds into the multiple pathways contemporary students are invited to follow both now and into the future.

6. Discussion on the proposed revisions to NSW senior secondary Science courses

There are a range of approaches for consideration in meeting the future learning needs of students in the study of Science.

Potential restructuring of the subjects within the 'Science' curriculum will cater for a broad range of students and allow for the integration of project and research-based opportunities. This may include the development of 4 x 25 hour modules in the Preliminary and HSC courses (currently 4 x 30 hours) with a 40 hour multidisciplinary project to form a 2-unit program of study. The authentic project/research component could be designed engage a broader range of learners. Existing structures can be maintained by schools and opportunity can be presented for schools to move to integrated studies, project-based models of learning and extension in any of the sciences.

Students who choose to study the proposed new Senior Science course could combine modules developed for the Biology, Earth and Environmental Science, Chemistry and Physics courses to cater for their needs and form a multidisciplinary study of Science.

The recommendation to review the course options emerges from the following data. The table provides the number of students currently entered in each senior secondary Science course option. Historically, options were included in each of the senior secondary Science courses to provide for student choice and to enhance interest and engagement. In practice, the options are largely chosen by the teacher and many have not been selected at all for a variety of reasons.

Table 8: Students enrolled in senior Science course options 2012 and 2013

Course	Option	Candidates 2012	%	Candidates 2013	%
Biology	Communication	11354	69%	11591	69%
	Biotechnology	974	6%	888	5%
	Genetics: The Code Broken?	3041	18%	3112	19%
	The Human Story	1121	7%	1164	7%
	Biochemistry	26	0%	35	0%
Chemistry	Industrial Chemistry	5584	52%	6012	55%
	Shipwrecks, Corrosion and Conservation	3302	31%	3438	31%
	The Biochemistry of Movement	122	1%	147	1%
	The Chemistry of Art	466	4%	328	3%
	Forensic Chemistry	1326	12%	1088	10%
Earth And Environmental Science	Introduced Species and the Australian Environment	1235	83%	1087	78%
	Organic Geology – a Non-renewable Resource	82	5%	56	4%
	Mining and the Australian Environment	37	2%	11	1%
	Oceanography	140	9%	239	17%
Physics	Geophysics	135	1%	74	1%
	Medical Physics	2954	31%	2854	30%
	Astrophysics	2153	23%	2017	21%
	From Quanta to Quarks	4151	44%	4502	47%
	The Age of Silicon	65	1%	88	1%
Senior Science	Polymers	249	5%	215	4%
	Preservatives and Additives	251	5%	261	5%
	Pharmaceuticals	1159	22%	1279	24%
	Disasters	3148	60%	3183	59%
	Space Science	407	8%	464	9%

6.1 Assessment and examination specifications

In many cases the structure of current assessment practices including HSC examinations will challenge a change in pedagogy. Current assessment practices lead to focusing learning on specific content statements. There is a need to create assessments that require students to transfer their acquired knowledge and skills to new contexts to demonstrate understanding and critical thinking.

There are currently no opportunities for projects and/or submitted works in the NSW senior secondary Science curriculum. Any move to STEM or project/research-based learning would need to consider appropriate assessment strategies, including school-based assessment opportunities, to cater for a wider range of learners. Additionally, the school-based assessment weightings and components for all Sciences are common and could be reviewed to better assess the diverse nature of individual subjects.

The context of student desire to maximise an Australian Tertiary Admission Rank (ATAR) score cannot be discounted in this discussion. As a matter of course, student subject selection and retention from Years 11 in 12 is driven by the desire to maximise their tertiary entrance ranking, and courses perceived as time-consuming or difficult are often avoided for study in Year 12.

7. K–12 learning continuum

Stages 1–3 Science and Technology

The study of Science and Technology in Years K–6 is intended to develop students' competence, confidence and responsibility through their experiences in Science and Technology within a broad framework. Students learn about the natural and made environments by investigating, by designing and making, and by using technology. Technology in this syllabus is concerned with the purposeful and creative use of resources in an effort to meet perceived needs or goals.

Stages 4–5 Science

The study of Science in Stages 4 and 5 intends to develop students' scientific knowledge and understanding, skills and values and attitudes within broad areas of Science that encompass the traditional disciplines of Physics, Chemistry, Biology and the Earth Sciences. As well as acquiring scientific knowledge and skills, students apply their understanding to everyday life and develop an appreciation of Science as a human activity. Students are invited to learn about the need to conserve, protect and maintain the environment, the use and importance of technology in advancing Science, and the role of Science in developing technology. Students also develop an appreciation of, and skills in, selecting and using resources and systems to solve problems.

Stages 6 Science

The current senior secondary Science courses recognise that students take different pathways beyond school. The senior secondary Science courses offered currently include Biology, Chemistry, Earth and Environmental Science, Physics and Senior Science. The subject matter of these courses attempts to recognise the differing needs and interests of students by providing a structure that builds upon the foundations laid in Stage 5, yet recognises that students entering Stage 6 have a wide range of abilities, circumstances and expectations.

8. Teaching standards and teacher education

The BOSTES supports quality teaching in all NSW schools. A minimum standard of teacher quality applies uniformly throughout the country in order to ensure rural and socially disadvantaged communities a level of teacher quality comparable to that available to students in advantaged metropolitan locations.

The BOSTES oversees a system of accreditation and recognition of a teacher's professional capacity against professional standards. Part of these responsibilities is to approve initial and continuing teacher education courses and programs.

Currently, there are 76 accredited secondary initial teacher education programs in New South Wales, delivered through 17 institutions. Of these, 33 initial teacher education courses allow graduates to qualify to teach within the Science key learning area in a secondary context. Alternative pathways also exist to post graduate teacher education courses.

Teacher ongoing professional development enables teachers to remain abreast of contemporary practices and knowledge in Science.

Professional development is a critical element for ensuring quality student learning outcomes, together with ensuring staff are professionally satisfied and motivated. Opportunities exist for the development of partnerships between tertiary and secondary schooling. Further, the impact of digital technologies and 21st century learning will require review of pedagogical approaches to Science teaching. These approaches include:

- project-based learning and assessment
- collaborative learning to develop knowledge, analyse situations and test theories and laws
- the use of digital tools to collaborate locally, nationally and globally on Science projects
- improved ICT integration and increased use and manipulation of data
- practical and integrated approaches to teaching Science.

APPENDIX 1

Findings from the 1997 Science Symposium

The summary of this report found that participants indicated that the study of Science should be the overarching theme and that the disciplines be subsets of that study with integration of Science courses possible and topics included that could be integrated with, or also appear in, the syllabuses of other Science disciplines, for example, topics in biophysics and biochemistry. It was suggested that subjects should not be stand alone. The authentic nature of the courses and investigation of current issues affecting students was a common theme where content was to be selected that should attract students and should always be tested to be satisfying their interests. The courses were to be designed to be relevant to students' lives and contribute to their physiological, environmental, social and vocational needs.

The symposium participants also concluded that:

- students should be required to complete a major project. This project and possibly an accompanying logbook should be part of their formal assessment. It could be a practical research project, a simulation or based on library research. The project should be:
  - student-directed
  - multidisciplinary
  - based on scientific methodology and research techniques
  - work-place based (optional)
- the influence of the examination needs to be considered. Separate assessments of projects and practical works should be included in addition to formal examinations. Problem-solving skills should be assessed
- preferably, all modules should include field work but this may not be workable for all schools and may have equity implications
- appropriate technology is required to enable teachers to draw on scientific knowledge and skills from all the relevant disciplines.

In conclusion, the opinion of many at the conference in regard to the future structure of Science courses was that despite the possibility of overlap with other discipline subjects, consideration must be given to the interlinking of Science disciplines.

References

Casotti, G, Rieser-Danner, L & Knabb, MT 2008, 'Successful implementation of inquiry-based physiology laboratories in undergraduate major and non-major course', *Advanced Physiology Education*, vol 32, pp 286–296.

Chubb, I 2013, *Science, Technology , Engineering and Mathematics (STEM) in the National Interest: A Strategic Approach*, available at <http://www.chiefscientist.gov.au/wp-content/uploads/STEMstrategy290713FINALweb.pdf>.

Clark I & James, P 2005, *Blended learning: An approach to delivering science courses on-line*, OODLA Conference, Adelaide, pp 19–24, available at <http://science.uniserve.edu.au/pubs/procs/wshop10/2005Clark.I.pdf>.

Cobern, W, Schuster, D, Adams, B, Applegate, B, Skjold, B, Undreiu, A, Loving, CC & Gobert, JD 2010, 'Experimental comparison of inquiry and direct instruction in science', *Research in Science & Technological Education*, vol 28, no. 1, pp 81–96.

Covill, D, Patel, B, & Gill, D 2013, 'Flipping the classroom to support learning: an overview of flipped classes from science, engineering and product design', *School Science Review*, September, vol 95, no. 350, pp 73–80.

Crowther, P & Savage, S 2008, 'The changing role of universities and flexible course re-development', in CIB W89: International Conference in Building Education and Research, 10–15 February, Kandalama, Sri Lanka.

Eberlein, T, Kampmeier, J, Minderhout, V, Moo, RS, Platt, T, Varma-Nelson, P & White, HB 2008, 'Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL', *Biochemistry and Molecular Biology Education*, vol 36, no. 4, pp 262–273.

Freeman, S, Eddy, SL, McDonough, M, Smith, MK, Okoroafora, N, Jordta, H & Wenderoth, MP 2014, 'Active learning increases student performance in science, engineering, and mathematics', *Proceedings of the National Academy of Sciences USA, vol 111, no. 23,* retrieved from <www.pnas.org/content/early/2014/05/08/1319030111.full.pdf+html>.

Goodrum, D & Rennie, L 2007, *Australian School Science Education National Action Plan, 2008–2012 Volume 1: The national action plan*, DEST, Canberra, retrieved from <www.academia.edu/1157498/Australian_School_Science_Education_National_Action_Plan_2008-2012_Volume_1_The_national_action_plan>.

Inel, D & Balim, A 2010, 'The effects of using problem-based learning in science and technology teaching upon students' academic achievement and levels of structuring concepts', *Asia-Pacific Forum On Science Learning & Teaching*, vol 11, no. 2, pp 1–23.

Kearney, S 2012, 'Improving engagement: the use of "Authentic self-and peer-assessment for learning" to enhance the student learning experience', *Assessment & Evaluation in Higher Education*, vol 38, no. 7, pp 875–891.

Lovell K & Vignare K 2009, 'MSU medical colleges blended learning for first year science courses: Uniting pedagogy to maximize experience and real world limitations', *Journal of Asynchronous Learning Networks*, vol 13, no. 1, pp 55–63.

Oliver, B 2013, 'Graduate attributes as a focus for institution-wide curriculum renewal: Innovations and challenges', *Higher Education Research & Development*, vol 32, no. 3, pp 450–463.

Ryan, RM & Deci, EL 2000, 'Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being', *American Psychologist*, vol 55, no. 1, pp 68–78, retrieved from <www.youblisher.com/p/7435-Self-Determination-Theory/>.

Spronken-Smith, R & Walker, R 2010, 'Can inquiry-based learning strengthen the links between teaching and disciplinary research?', *Studies in Higher Education*, vol 35, no. 1, pp 723–740.

Toth, EE, Suthers, DD & Lesgold, AM 2002, '"Mapping to know": The effects of representational guidance and reflective assessment on scientific inquiry', *Science Education*, vol 86, pp 264–286.

Towndrow, P, Ling, T & Venthan, A 2008, 'Promoting inquiry through science reflective journal writing', *Eurasia Journal of Mathematics, Science & Technology Education*, vol 4, no. 3, pp 279–283.

Tytler, R 2007, 'Re-imagining science education: Engaging students in science for Australia's future', *Australian Education Review*, no. 51, <http://research.acer.edu.au/aer/3>.

Wai-Yin, P, McNaught, C, Lam, P & Kwan, HS 2009, Improving assessment methods in university science education with negotiated self- and peer-assessment', *Assessment in Education: Principles, Policy & Practice*, vol 16, no. 3, pp 331–346.

Woltering, V, Herrler, A, Spitzer, K & Spreckelsen, C 2009, 'Blended learning positively affects students' satisfaction and the role of the tutor in the problem-based learning process: Results of a mixed-method evaluation', *Advances in Health Sciences Education*, vol 14, no. 5, pp 725–738.