Science Teachers Association NSW Position Paper on NSW Science 7 –10 Science syllabus 2022

1 Background

The Science Teachers Association of NSW (STANSW) exists to advance the profession of science teachers in NSW through the provision of quality professional learning, information, and advocacy for primary and secondary science educators. A strong science education is essential so that every school leaver has an understanding of the core concepts and the nature and practice of science, particularly the ability to think scientifically. We aspire to a society founded on the development of scientific language, logic, and problem-solving that produces scientifically literate citizens.

In 2020, Professor Geoff Masters proposed an ambitious reform that sought to re-organise both the structure and content of the wider curriculum so that students would be placed at the centre of decisions, meaning that at an individual level, students are supported towards educational attainment.

The curriculum imagined by Professor Masters would enable students to learn with deep understanding, build skills in applying knowledge, and be supported at an individual level to progress along a learning continuum. There were innovative and exciting components to the final review report and STANSW was supportive of this.

The recently released draft NSW Science syllabus is part of the process of implementing these reforms. STANSW acknowledges the work of NESA through this process and welcomes the opportunity to work in partnership to design a syllabus that achieves its ambitious aims.

2 Methodology of STANSW's Syllabus Review

STANSW's review of the draft Syllabus involved:

1. A think tank, comprised of senior science teachers and academics, was convened. Meetings were held on 1 and 8 November and were attended by 24 participants. The Think Tank undertook a detailed analysis of the syllabus, which has formed the body of recommendations in this paper.

2. The STANSW Head Teachers Network (HTN) was convened to review the syllabus. 17 HTN members participated in the review, which was held 3 November. The Head Teachers Network teachers undertook a separate analysis of the syllabus, which was then incorporated into the recommendations in this paper through thematic analysis.

3. An online survey was circulated amongst STANSW members and followers. The survey was open for one week (Monday 14 November to Monday 21 November) due to the brief timeframe of the consultation process. 192 respondents answered the survey, including 175 current practicing teachers, 4 retired teachers, 5 academics, and 7 who listed their occupation as "other". 61% of respondents were from Sydney metropolitan schools, 35% were from regional or remote NSW schools, and 4% were from other locations. Data from the survey has been incorporated throughout this paper, and sample responses from open questions are included in appendix B.

For ease, we will refer to the opinions in this paper as being STANSW's, however they have been synthesised from these extensive review activities.

3 Review Findings

3.1 Strengths of the new syllabus

STANSW acknowledges NESA's leadership in undertaking this syllabus revision, as it was well needed. Some strengths of the new draft syllabus include:

- STANSW agrees there is a need for reform

- The rationale and aims of the syllabus are strong
- Skills outcomes show some progression of depth of understanding across stages
- The inclusion of depth studies, including opportunities for students to pursue their interest
- The Inclusion of academic integrity (investigating scientific truth - ethical issues associated with using or citing secondary data or information)
- The inclusion of environmental sustainability
- There has been a meaningful attempt to include female scientists in examples

3.2 Feedback on the aspired reforms of the syllabus

Despite the strong rationale and evidence base provided, our overall conclusion is that the draft syllabus does not yet meet the intended reform goals. We have summarised our concerns along with key recommendations, structured according to the "reforms evident in the syllabus" section of the draft. Additional details follow in the appendices.

3.2.1 A new structure that highlights essential content

STANSW is concerned that the current structure does not clearly present the essential knowledge and skills students require. The arrangement of the focus areas creates confusion, as does the approach to integrating the working scientifically processes. There is a focus on content statements, which seems to privilege declarative knowledge, and the working scientifically skills are addressed inconsistently across the syllabus using multiple incongruous approaches:

- The working scientifically processes (page 8) are mapped to skills outcomes (p15), though this connection is not made explicit, and not all aspects of the processes are included within the skills outcomes.
- *All* processes are said to be incorporated into *all* focus areas through the inclusion of an overarching outcome, but this outcome is phrased to focus only on "communicate scientific ideas" (which is only one of many skills for science).
- Each focus area contains 1-2 skills outcomes in addition to the overarching working scientifically outcome- this is confusing.
- Page 10 lists expectations for creating written texts. These are written as outcomes (and overlap with the skills outcomes) but their place in the syllabus is unclear.
- There are three focus areas (nature and practice of science, investigating scientific truth, and data science) that have content statements relating only to working scientifically skills (as well as scientific dispositions), in the absence of discipline-based knowledge content.

- Working scientifically skills are also included explicitly (embedded) amongst the content statements for the other focus areas.
- Use of these skills are also implied whenever a content statement includes an instruction to “investigate”.
- Finally, there is the requirement for depth studies each year, which must each include 2-3 working scientifically processes

In STANSW’s survey, when asked whether the syllabus has a structure that highlights essential content:

44% either disagreed or strongly disagreed
34% were neutral
22% either agreed or strongly agreed

Key Recommendations

- Include the working scientifically skills the way they are currently are in stage 6, with skills outcomes described richly, separate to the knowledge and understanding outcomes.
- Remove the three skills-only focus areas, instead incorporating these important ideas as cross-cutting skills. Skills cannot be taught in the absence of content, and that content needs to be meaningfully structured.
- If skills are to be mapped to specific content statements, this should be included within supportive teaching resources, not mandated by the syllabus. This will enable highly proficient teachers to program flexibly and creatively.

Further feedback related to this reform

Issue	**Examples**	**Recommendation**
Structure	The lack of numerals or identifiers makes it difficult for programming and teacher communication.	1. Insert numerals or alphabetical identifiers for focus areas, content groups, and content statements.

Consistent language between skills, outcomes and content	There are problems across the Syllabus with consistent language between skills, outcomes and content. The ACARA Outcomes are clearer, and there is opportunity for the NSW Syllabus to align more closely with this.	1. Align outcomes with the ACARA Outcomes
Working scientifically skills are too prescriptive when embedded with content in the focus areas	This reduces flexibility and opportunity to practice a skill authentically as the moment arises. Working scientifically processes are interrelated and should not only be taught as "chunks" but part of meaningful scientific investigations.	1. Remove the skills link to the content 2. Reinstate Working Scientifically as currently used, with a few deletions only.
Processing	Processing data and information is cluttered and dense.	1. Include more than one dot point as this skill is very large.
Loss of variety in Working scientifically skills	The loss of the range and variety of Working Scientifically skills outcomes will mean that only the experienced teachers will have access to this knowledge. New teachers coming in will never have access to this. We need the skills we have currently, just tidied up.	1. Incorporate a consistent framework for skills 2. Tidy up existing skills. Do not rewrite in this new format.
Values, attitudes and dispositions	This has been removed and is a gap in important content.	1. Reinstate values, attitudes and dispositions

3.2.2 Explicit outcomes and content that indicate essential knowledge, understanding and skills

STANSW noted an inconsistent use of statements and descriptors in the new syllabus. Judicious use of verbs in the syllabus is critical for specifying the expected level of understanding (Adelman, 2015). Without using verbs, teachers won't know the level of depth required in their teaching. In addition, there are inconsistencies in the level of granularity in the outcomes and content. For example, the first point in genetics is the whole topic statement for Australian Curriculum.

In STANSW's survey, when asked whether respondents agreed with the way in which outcomes are expressed and the removal of verbs such as 'identify', 'describe' and 'explain':

51% either disagreed or strongly disagreed
21% were neutral
27% either agreed or strongly agreed

Furthermore, the current set of outcomes and content statements is lacking aspects considered essential to reach the goals of an engaged, scientifically literate society that can apply their knowledge of science for decision-making. Essential "big ideas" in science are missing, for example, astronomy and our place in the universe, and the importance of heat as a form of energy.
The *NSW Government response to the NSW Curriculum Review final report* supported the recommendation to:

> "Make explicit in new syllabuses for every subject that skills in applying knowledge are part of the intended learning, and show how these skills are to be developed over time. These skills include subject-specific skills, but also skills in using technologies, sourcing and analysing information, critical and creative thinking, collaborating, and communicating." (p16)

Developing skills in *applying* scientific knowledge requires students to engage in rich, active, collaborative problem-solving activities that are embedded in relevant contexts. The "science in context" statements at the end of each focus area do not encourage teachers to take a context-first approach to enable students to make relevant connections with their local contexts. Such meaning-making is essential not only for deep learning and the application of knowledge, but also for student engagement and aspirations towards careers in STEM.

Engaging with the emerging issues of society into our future will require students have the opportunity to apply not only the knowledge and skills of science but also an understanding of science as a human endeavour and the ethical, legal, and social implications of applications of science. The PISA 2024 Strategic Direction (OECD, 2020) makes it very clear that students require not only the knowledge and skills of science but also "Using scientific knowledge for decision-making and action, as young people need the capacity to actively use their scientific knowledge to decide on courses of action, and to create new value." The socioscientific contexts that support such learning are not given explicit focus in this draft of the syllabus.

Key Recommendations

- Utilise verbs to explicitly indicate the level of depth expected, with increasing complexity

- Bring in focus questions / big Ideas and authentic contexts
- Reintroduce Astronomy and Heat

Further feedback related to this reform

Issue	**Examples**	**Recommendation**
Inconsistent use of statements and descriptors	The language across the syllabus is inconsistent, and there are many statements as well as descriptors used throughout. For example, 'Characteristics of living things' are all different grammatical structures that don't indicate what students are expected to do or learn.	1. Use verbs consistently. Some examples include: Change: *'The Doppler Effect of waves' to: 'use wave and particle models to explain…',* *Change: 'Types of reactions..." to: 'explain types, rates and factors that affect reactions'*
Contexts follow after content	Content is learned best when embedded within meaningful contexts that are relevant to student's life.	1. Structure the syllabus to enable teachers to situate content knowledge within meaningful contexts and allow students to apply the knowledge and skills to authentic, real-world problem-solving. 2. At very least, move science in context to the top of the focus area.
Removal of Heat and Methods of Heat Transfer	In our survey, 72.8% of respondents either disagreed or strongly disagreed with the question: *Do you agree that it was appropriate to remove: heat and methods of heat transfer from stage 4/5*	1. Reinstate Heat and Methods of Heat Transfer

Removal of Astronomy	In our survey, 72.8% of respondents either disagreed or strongly disagreed with the question: *Do you agree that it was appropriate to remove: Astronomy*	1. Reinstate Astronomy

3.2.3 A clear progression of science learning from Stages 4 to 5, allowing students to extend their knowledge, understanding and skills

A syllabus needs to provide an overview of the progression of key concepts for K-12. Professor Masters' report (2020) strongly recommended identifying 'key concepts' and ensuring there is progression over time. Currently in the draft Syllabus, concepts are arranged inconsistently into focus areas, without clear progressions, and often with considerable "hidden" required knowledge. It is essential that the syllabus is based on a clear K-12 concept map that works backwards from Stage 6 and illustrates how knowledge will develop over time. Without this mapping, the relationship between stage 4 and stage 5 is unclear. It is also unclear what prerequisite knowledge is required from stage 3.

In addition, we have identified examples where content is not stage appropriate and unordered, as well as content that has been brought down from Stage 6.

In STANSW's survey, when asked whether overall the syllabus was well-designed and would achieve the aims of improved student learning and progression:

58% either disagreed or strongly disagreed
23% were neutral
17% either agreed or strongly agreed

Key Recommendation

- Develop a concept map that illustrates how ideas build over time. This would involve mapping the conceptual development required for deep content knowledge starting with final year attainment standards and use a backward mapping process to design attainment levels across a 12 - K continuum, based on empirical evidence relating to students' abilities and with reference to appropriate theories of knowledge.

- This is essential for the fulfillment of Professor Master's key recommendation, that was supported in the government's response: "Decide how this core content is to be sequenced through new syllabuses, informed by evidence of how increasingly deep knowledge and understandings in a subject commonly unfold and are best developed over time." (NSW Government response to the NSW Curriculum Review final report, p16).

Further feedback related to this reform

Issue	**Examples**	**Recommendations**
Core ideas are not clearly articulated, and there is no clear progression in terms of increasing sophistication over time	Body systems appears in 'Systems' then Homeostasis and nervous system appears in 'Disease. In addition, Types of energy is under 'change', then again 'energy'. No progressions of ideas are tracked or presented. Primary is not included, and literature on learning progressions don't seem to be used. Teachers would benefit greatly by having this published to use.	1. Develop a concept map. *For examples, see US NGSS* https://www.nextgenscience.org/sites/default/files/resource/files/AppendixE-ProgressionswithinNGSS-061617.pdf https://thescienceteacher.co.uk/wp-content/uploads/2018/12/Porgression-of-big-ideas-.jpg
Logical progression of conceptual understanding is missing in many sections of the syllabus.	The learning of prerequisite content knowledge often appears *after* it is required in the syllabus dot points. At times it appears in the same Focus Area, at other times it is not in the same Stage. More careful consideration must be made regarding how the knowledge of concepts is constructed/developed in the Science classroom.	1. As above, develop a concept map

	For example, precursors needed for students to learn to balance equations successfully include: - elements and their symbols - compounds – simple binary compounds (-ides); patterns of naming and what this tells you about composition and **formulae** (as they meet them through practical work) - hence valency - more complex compounds (-ates); patterns of naming and what this tells you about composition and **formulae**(as they meet them through practical work) - the idea that the products of a reaction can only be made from elements which are present in the reactants - valence ideas extended through work on types of bonding - law of mass action from experiments - word equations from actual experiments - modelling using toothpicks and plasticene to balance formula equations - patterns in equations from similar reaction types - complete formula equations including state symbols A few of these are included in previous sections, but not all. Other examples are below:	

	Water (Page 20): *Solid (S), liquid (l) and gas (g) as different states of water as it moves through nature.* Matter, atoms and bonds (Page 26): *Identify the different states of matter in everyday objects.* Disease (Page 34): *Factors and causes of non-infectious diseases* requires a knowledge of DNA, genetics and mutations (Origin and Continuity of Species: Page 40). Within Origin and continuity of species (Page 40), the theory of evolution (in which variation in the species due to mutations is a vital component) is addressed before Genetics and mutations. Rearrange Types of Reactions (Page 42): *Write word and balanced formula equations, and use symbols to represent a reactant or product state as subscripts after the formula*. Students require a knowledge of nomenclature, writing chemical formula and solubility rules to achieve this outcome. "Interpreting" chemical formulas (page 27) is not adequate. Remove from Stage 5 and leave in stage 6	
Progression of metalanguage over time.	In the current draft syllabus there is no learning progression towards the metalanguage and development of accurate mental models (eg replacing misconceptions)	1. Create a concept map showing what the learning progression is. For example:

		https://thescienceteacher.co.uk/wp-content/uploads/2015/07/Big-Ideas-of-Science-Tree.jpg
Harlen's research has not been applied.	Harlen has put big ideas into a progression but the draft syllabus has included some of the ideas for 14-17 year olds into stage 5 when they should be in stage 6	1. Big ideas – Use these for developing new focus areas and link the ideas about science all the way throughout the syllabus.
Cognitive demand is inconsistent across disciplines and Stage inappropriate in multiple cases.	Cognitive levels of content are inconsistent with stage 4 and 5. There are instances of stage 2 and stage 6 concepts included. For example, explaining chemistry phenomena often requires a deep understanding of abstract concepts. In Stage 4: Matter, atoms and bonds (Page 26), the outcome is: • *Explains how the chemical properties of matter enable atoms to bond.* This outcome is not directly addressed in the subsequent content, though "patterns and relationships found in the periodic table" is (Periodicity). Electronegativity (electron affinity) and electrostatic interactions will cause atoms to form bonds. The factors that influence electronegativity (number of protons, distance between valence electrons and attractive force of the nucleus and number of shielding electrons) is one of the more complex concepts for students to understand when learning Periodicity in Stage 6. This requires a knowledge of atomic structure, in particular electron configuration (which appears later in the same focus area) and a	1. Re-write outcomes to be stage appropriate (for example, the "Matter, atoms and bonds" outcome. Potential wording: *Describes matter as particles that may interact with each other to form bonds.* Alternatively, move this outcome to a different stage (late Stage 5 or 6). 1. Care must be taken, as simplifying chemical bonding as a concept often leads to the establishment and reinforcement of

	synthesis of the effect of three different factors that sometimes interact in complex ways (i.e. fluorine does not have many protons, but the distance to this attractive force is very small, allowing it to form bonds very readily).	misconceptions (Hunter et al, 2022).

3.2.4 Content that has been arranged in multidisciplinary focus areas to allow students to build a network of interrelated knowledge.

STANSW is concerned that the organisation of content into multidisciplinary strands is implemented in a way that will increase cognitive load for students and will be exceedingly difficult for teachers to program. Evidence has demonstrated that students need to develop foundational knowledge with clear relational connections before moving to the extended abstract phase where they can create interrelated knowledge networks (Biggs & Collis, 2014).

The syllabus draft itself recognises the importance of student's understanding of the disciplines of science (biology, physics etc). Yet the syllabus does not reflect these long-held disciplinary norms. (Though many of the focus areas do focus primarily on one discipline).

In addition, schools cannot teach content that does not fit their context (Mims, 2003). The focus areas do not integrate content, context and skills. It is very knowledge content driven. This issue could lead to content being taught without skills being taught, and will be difficult to program.

In STANSW's survey, when asked whether the organisation of content in interdisciplinary strands under Focus Areas has been implemented well in the draft syllabus:

62% either disagreed of strongly disagreed
6% were neutral
6% either agreed or strongly agreed

Key Recommendations:

- Reorganise the syllabus into Individual discipline strands (living world, physical world, chemical world, earth & space) aligned with ACARA so that teachers can program multidisciplinary work
- Change statements to focus questions

Further feedback related to this reform:

Issue	Examples	Recommendations
Lack of evidence for multidisciplinary teaching	The use of multidisciplinary teaching can be problematic for 7 – 10 teachers. Students need to learn the disciplinary knowledge before they can start to do interdisciplinary learning. SOLO taxonomy clearly shows how students build their complex and relational ideas from single concepts. They are unable to relate ideas until they have reached formal thinking stage.	1. Incorporate a framework for teachers to select their own authentic opportunities for doing multidisciplinary teaching at the appropriate time, and within the context of their school environment.
Multidisciplinary theming is based on tenuous connections	For example, relating ecosystems to body systems requires high level systems thinking that needs to be scaffolded through the development of the separate ideas first. The big ideas being built in the body and plant systems content groups are not related to systems, but rather the relationship between form and function.	1. Any attempts at multidisciplinary arrangements of concepts should be based on real-world problems rather than high order conceptual relationships. 2. Enable students ample opportunity to apply

	"Change" might be a good theme for an English literature unit, but it is unrealistic to suggest that students can make connections between changes in society, changes in forms of energy, changes in chemical structure, and changes the planet over time, *before* they have had a chance to develop a strong understanding of these concepts.	transdisciplinary knowledge during meaningful problem-solving once foundational understanding has been established.

4 Next Steps

STANSW agrees with the need for reform of the NSW Syllabus and believes that strong leadership is required for this reform to be achieved. The feedback provided through the points above, as well as supplementary analysis given in Appendix A, is intended to help inform NESA's next steps and develop a syllabus that is fit for purpose and will position NSW 7-10 students for success.

For this reform process to be successful it will require commitment of adequate resources for its implementation. In addition, consultation with the Professional Teachers Associations should be considered a major component of the reform. STANSW wants to be involved, and wants this reform to succeed.

STANSW welcomes the opportunity to work in partnership with NESA to promote and implement the reforms and support the development of models that might demonstrate the application of these reforms including the rewrite of a new syllabus. We look forward to continuing to engage with this syllabus development as the process progresses and we are available to actively contribute to the work of NESA. Our membership has a huge array of wisdom from regional, rural, metropolitan and academic expertise and we can easily access this wide range of knowledge.

Appendix A – Supplementary analysis

The evidence-base of the Syllabus

Issue	Examples	Recommendations
The Syllabus is not consistent with its evidence base	The evidence-base cited in the Syllabus does not align with the qualities of the new syllabus. For instance, the Bravo, Gonzalez & Riess (2021) study cited found that the teachers "were more interested in their own creation and development of big ideas rather than simply adopting the existing, official published framework and adhering to what is said". This supports the view that the curriculum should outline key ideas and how they develop, with teachers given scope to reinterpret those ideas into contexts/narratives. In addition, Harlen et al (2015) also explained that 'for each of these big ideas the progression in development is described in terms of a narrative; a story of how small ideas build into bigger ones''. The syllabus does not show a progression of ideas that build and progress over time.	1. Ensure the principles in the Syllabus are consistent with evidence-base cited. 2. Develop a concept map that illustrates how ideas build over time (see further detail in item 3)

Use of Australian literature in the evidence base is lacking.	The majority of the evidence-base cited in the new syllabus is from overseas, which limits its generalisability and applicability in the Australian context. There are several seminal local research papers that are missing from the current syllabus.	1. Include seminal local research papers that will be applicable in the local context. **See Appendix D**
Inconsistent and incomplete use of evidence.	Papers cited have not been systematically reviewed. Instead, certain components have been cherry picked and incorporated into the draft syllabus. For example: 1. Harlen et al (2015) promotes inquiry pedagogy as and when needed, however the use of inquiry has been removed. 2. Taber (2014) states "student learning is incremental, interpretive and iterative", and identifies the need for a spiral curriculum which is not evident in Stages 4 and 5. In addition, without seeing stages 3 and 6, it is impossible to see how the ideas build over time.	1. Reinstate inquiry question 2. Develop a concept map that illustrates how ideas build over time (see further detail in item 3)
Lack of socio-scientific content and issues	There is limited reference to socio-scientific, ethical issues and values in the syllabus. Whilst this allows scope for teachers to develop their own socio-economic contexts, it means that the syllabus is very content driven. There could be an undesirable result of	1. Retain the ACARA *Science as a Human Endeavour* at the appropriate levels and continuum.

	teachers teaching content only, particularly for early-career teachers. There is only one reference to ethics in stage 5: *"conduct a case study of Henrietta Lacks to create a written text discussing the ethical implications of the continued use of the HeLa stem cell line."* This is introduced suddenly, without reference to the ongoing development of science research values.	2. Develop a map to show how the teaching of ethics is progressed throughout K-10 3. In the Stage 5 Henrietta Case study, reword this to "use an ethics framework to create a written text discussing the ethical implications of a genetic technology" and give HeLa cells as an example.

Issues with Focus Areas

Stage 4 Nature and Practice of Science	The evidence base and syllabus content does not include seminal work in science education, for instance, in the Nature of Science (eg. McComas & Clough, 2020) This content cannot be taught without a context. The nature of science is not included - for instance, the difference between a theory and a law. The nature and practice of science is not appropriate as a focus area; it is a way of thinking about the ways of science and must be linked to context or a story of science discovery.	1. Collapse the "Nature and practice of science" and "investigating science truth" into one "Nature of Science" unit. 2. Include some aspects of known tenets of Nature of Science, including: • Scientific Investigations Use a Variety of Methods; • Scientific Knowledge Is Based on Empirical Evidence; • Scientific Knowledge Is Open to Revision in Light of New Evidence;

		• Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena; • Science Is a Way of Knowing; • Scientific Knowledge Assumes an Order and Consistency in Natural Systems; • Science Is a Human Endeavor; and • Science Addresses Questions About the Natural and Material World.
Stage 4 Scientific Cause and Effect	Cause and Effect can be found in every aspect of science and teaching it in isolation will have unknown impacts. It is not possible to teach this as a focus area. Students will be confused when the teacher jumps around between biology, chemistry, physics etc.	1. Remove the Focus Area and integrate this within topics in the syllabus
Stage 4 Water	Water as a focus area lacks a link to the content listed. There is no link to the microorganisms that could live in water. The examples are also limited and do not work.	1. Rethink the intent of a focus area and change to this to a big idea or key concept
Stage 4 "Systems" and Stage 5 "Disease" - inconsistent organisation of focus areas	The organisation under the focus areas is problematic – for example, one focus area is 'systems' and another is 'disease'. In systems – cells needs to be linked here with body systems. Systems is a principle of science and is not a focus area.	1. Rethink the intent of a focus areas and change to this to a

	Disease is a current module in year 12 Biology. Body systems doesn't make sense if 'cells' are covered in 'Life', as the 'cell' is the key part of the system. One cannot understand 'cells' without systems. As with other units, statements are unclear and context is missing. It is better to have individual topics and then potentially 'cross cutting concepts' which can be explored separately. For these reasons, this will be very difficult for teachers to organise into units. In addition, the topics and outcomes appear more Stage 6 than stage 4.	big idea or key concept (See ACARA document) 2. Develop topics which are more strongly conceptually linked together 3. Re-write outcomes to be Stage appropriate (see section 5)
Stage 4 Systems	It will be difficult to make a link between ecosystems, body systems and plant systems, and they will likely be taught independently. Having the 'systems' topic before the actual systems study exacerbates this. In addition, there is too much content for one unit (ecosystems, body systems, plant systems)	1. Have systems after the topics. 2. Remove one of ecosystems, body systems, plant systems.

Topic in context	In classification it is unclear whether this is just an activity. Often the students are not prepared to do it.	1. Make a descriptor that can become an open investigation or depth study.
Stage 4 Change	There is an unusual and not a very easy collage of ideas and concepts. There is no conceptual flow.	1. Rethink this focus area
Stage 4 Investigating Scientific Truth	There is no such thing as 'scientific truth'. This is too broad and most experienced teachers would go to the depth we go to now. Teachers will not do working scientifically skills unrelated to content or context. In addition, the first three contents are very different to pseudoscience. Seems disjointed.	1. Rethink this focus area
Stage 5 Origin and continuity of species (40-41)	Lots of content from this unit is from Stage 6 Biology	1. Significant and detailed recommendations are provided in **Appendix C.**
Stage 5 Data science	This could be good to link working scientifically and the contexts, however this shouldn't be a discrete unit, rather integrated throughout studying other branches of science, taught in context.	1. Reorganise the syllabus into Individual discipline strands
Stage 5 Energy	Energy, Resources and Environmental sustainability are all very similar. This will feel repetitive to students and likely lead to disengagement.	1. Reorganise the syllabus into Individual discipline strands

Resources and Environmental sustainability		

Stage-appropriate content and skills

Issue	**Examples**	**Recommendations**
Stage 4 Page 17 Example 8	CRISPR, mRNA = is too advanced for stage 4, they don't have the background understanding	1. Move to stage 6
Stage 4 Matter atoms and bonds	Stage 4 nucleon is unnecessary Page 26. It is only needed when covering NMR	1. Leave nucleons in Stage 6
Stage 4 Page 26 and 27 matter, atoms and bonds	Stick to the word particles in stage 4 and do not touch atoms, ions or molecules until stage 5 when you talk about bonding. Example 56 include Lewis electron dot structures is too difficult for stage 4 Energy levels is inappropriate for stage 4	1. Move reference to atoms and subatomic particles to stage 5 2. Move atomic structure to Stage 5 3. Move electrical neutrality to Stage 5 4. Move all bonding to stage 5/6. Focus on forces and more general bonding terms in Stage 5

		5. Move the term nucleons to stage 5 6. Move the cations and anions to stage 5 7. Move example 56 to stage 5 8. Move energy levels to stage 5
Stage 4	Bonding and formation of ions in stage 4 will be difficult, students not ready for it Level of depth is not appropriate for Stage 4 students.	1. No flame tests - the concepts of ions is beyond them at this stage.
Stage 5 Page 43	Example 151 There has not been enough chemistry to do photosynthesis and respiration. Synthesis and Decomposition reactions are Stage 6 chemistry. We do not want to teach Krebs cycle so make the points more age appropriate. In addition, the reaction in context is unrealistic for stage 5 students.	1. Move to Stage 6 2. Suggest: *Explore the connection between a chemical reaction and a real world application in industry, nuclear energy or medicine.*
Stage 5 Page 42 Rate of chemical reactions	It seems that are lot of the examples are extensions rather than elaborations. For example, where have students learned about moles and why would they at this level? In addition, nuclear decay is too abstract for stage 5 and unnecessay unless students are studying chemistry or physics in stage 6	1. Example 144 – delete molarity 2. Move nuclear day to stage 6
Stage 5 Page 34	As previously noted, Disease is high order Biology from stage 6 – it is very challenging content to teach.	1. Simplify the content to make it stage appropriate

Disease		

Dichotomous presentation of Aboriginal and Torres Strait Islander perspectives

Syllabus Content:	**Examples**	**Recommendations**
Aboriginal and Torres strait islander perspectives are presented as a false dichotomy	There is False dichotomy between "Aboriginal peoples" and scientists of today. Traditional (or as we now use the term, customary) practices of "Aboriginal peoples" are not generic – they are specific to locations and clans. The syllabus needs a more authentic flow of Aboriginal peoples' traditional ways of knowing. Further consultation is needed on this area with Aboriginal and Torres strait peoples.	1. Re-write the sections that create comparison between "customary practices" and "modern practices" 2. Ensure the diversity of Aboriginal and Torres strait practices is clarified 3. The syllabus needs further consultation with Aboriginal people and better examples.

Incorrect science in the syllabus

Issue	**Examples**	**Recommendations**

Stage 4 Page 20 - Water "represent changes in the particle arrangement as the substance changes state".	This says nothing about the rate of motion or forces between the particles which are equally important but at a basic level (Johnson, 2013) This is needed for students to understand how the states of matter behave and their different properties.	*1.* Change to: "*Represent change in state in terms of* - *Relative positions of particles* - *Forces between the particles* - *Motion of the particles"*
"The properties of **substances** are due to their..."	This is an incorrect, and should say elements instead of substances.	1. Change to "The properties of **elements** are due to"
Example 55 and 56 page 26 - 27	This is usually an extension for different forms of matter.	1. Correction needed - change to an extension, rather than an example
NaCl is not a molecule; it is ionic.	Stage 4 Bonding - dot point 5 (terminology is wrong – using the term atom in ionic compound is incorrect – they are ions)	1. Correction needed
Atom as an ionic compound	Don't use the term atom in ionic compounds	1. Correction needed
Stage 4 *Page 18*	Contact vs non-contact forces are incorrect ideas. Forces - push and pull (primary) concrete and cause and effect. In 7 - 10 there there are more forces at workthat the 7-10 students don't yet knowing about. 4 fundamental forces (stage 6 - quantitatively) • Electromagnetic	1. Remove false categorisations – they cause misconceptions and confusion. There is no need for the terms contact, non-contact.

	• Nuclear
	  ○ strong
	  ○ Weak
	• Gravitational
		Fields are better and don't need the contact/non-contact.
		
		2. Twist is torque - a force that causes something to rotate around an axis. Do not list as a force.
		
		3. It is unnecessary to repeat push/pull in 7-10

Stage 4	In the Particle Theory in our syllabus (present and proposed) relating to solid, liquid, gas and change of state etc. the particles we need to look at are **atoms, molecules or ions** – at Stage 4 they do not need to know this (and should not be told these names) – they are all simply 'particles'. We are looking at the level of actual particles which exist in the substances students will meet in the lab and in everyday life.	1. Change language to kinetic theory of matter rather than particle theory to prevent teachers thinking it is about the structure of the atom.
*St*age 4 Categorization of types of forces as push, pull and twist	This is covered in Primary science and technology. A twist is a torque and should not be separated out here.	1. Remove from stage 4 2. Classify the types of forces as push or pull
Page 40 Stage 5 Original and continuity of species	Example 129 should be geological time scale, geographic	1. Correction needed – change Example 129

Stage 5 rate of chemical reactions Page 42 "The rate of a reaction can be measured by the time taken for a reaction to occur"	What is the purpose of this? The is no direction. Teachers know that you measure a rate by taking the time for something to happen. Is that what is intended? Then make it a generalisation so it can be applied when appropriate rather than specific to chemistry Rate is the event per unit of time.	1. Change to: *The rate of a reaction can be affected by factors including temperature, concentration and surface area.* OR *The rate of any event can be measured using the time taken for the event and can be calculated.*
Stage 5 Disease (Page 34): "Types and transmission of infectious and non-infectious diseases".	Transmission only relates to infectious disease. https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html	*Separate the two ideas.*
The properties of substances are...	Incorrect language	*The properties of elements are....*

Time allocation for Depth Studies

Syllabus Content:	**Issues Identified**	**Recommendations**
Stage 4 and Stage 5	While the majority of our teachers surveyed were positive about the inclusion of Depth Studies in the Syllabus, there will be no time to do depth studies at the moment. There is no	1. Use language similar to current SRPs.

	need to specify the time to do a depth study. Allow the teachers to allocate the time as they see fit. In addition, the language of the depth studies removes a teacher's ability to differentiate. Current SRPs are already happening well.	2. Remove the specification of time

Appendix B

Sample Survey Responses

1. **A structure that Highlights Essential Content**

The syllabus introduces new focus areas, several of which are political and involve use of only secondary data collected through complex scientific processes.

There needs to be a reduction in content.

Good units - minimal flexibility . Content on Machines does not prepare students for stage 6 physics. All students absolutely love the astronomy and it prepares students for stage 6 physics - is it possible to include it in this syllabus?

It appears like there has been little reduction in content. In fact the content has increased with the introduction of more complex Stage 6 content like balancing equations, equations of motion etc. This coupled with the inclusion of "Data Science" "Scientific Truths" and "Nature and Practice of Science" makes this a cluttered syllabus.

2. **Clearly Expressed Outcomes**

Needs verbs and improved terminology

The use of verbs such as describe, identify and explain should be used.

Broad outcomes are alright in principle; however, we make the syllabus too broad and then students and teachers don't know the scope expected from the syllabus and then sit exams (in junior years but especially in senior years) with explicit focus on content. The principle is good, but with written exams the way they are I think that using broad syllabus outcomes you disadvantage students and teachers.

Without verbs this will not be taught in enough detail to provide the foundation for stage 6 Chemistry. The last 2 sections belong in Stage 5 not stage 4. Perhaps the first point of the second section is stage 4 appropriate.

Explicit verbs indicate and scaffold to students and teachers how much depth is required for that outcome/content. It also prepares students for HSC style examination questions.

The lack of verbs in most content statements is a problem as these allow teachers to interpret the depth and breadth of teaching.

3. **A clear progression of science learning from Stages 4 to 5, allowing students to extend their knowledge, understanding and skills**

A syllabus needs to provide an overview of the progression of key concepts for 7-10. It is not a teaching program and fails to meet the remit of what a syllabus is meant to do

The syllabus does not allow for building deeper understanding through prior knowledge so students can make connections between different scientific concepts and apply this knowledge to new examples. The order of the units is problematic. E.g. complex ideas, such as electron shells, are introduced before the understanding of the periodic table. Additionally, the concept of energy is required in Stage 4 units, but the energy unit is in Stage 5.

The focus areas have been placed together clunkily with little to no clear link between concepts

Makes it more difficult for students to follow progression. Undermines teacher's abilities to provide cross-module/ cross-topic links and provide context.

How can students understand F=ma when they haven't yet covered motion?

Concepts beyond stage level; atomic structure (nucleons, electron sub-orbitals, decay reactions) are extension at best and not stage 4.

I wonder if there is overlap between Stage 5 and 6 Chemistry - especially in the Chemistry of organic compounds section and determining heat released on combustion.

Some of the contents are well above the level of stage 4 and 5.

I strongly disagree with the inclusion of the Bonding focus in Stage 4 matter. Way too hard for the average Stage 4 student. I also think that the dot point about mixtures in 'Water' should replace bonding in Matter. Whilst I agree with the inclusion of some dot points about Genetic Tech in Stage 5, I believe there are too many and that the Origin continuity of species unit is massive. Take out some of those genetic technologies dot point please!

The ideas behind the syllabus are good and will help students transition into Stag 6. However, the implementation is lacking and some content is too hard for the stages indicated or too hard for Stage 4-5 full-stop. The amount of time available in class needs to be considered, especially with the implementation of so many hours of depth studies. Depth studies should be way fewer hours.

4. Content that has been arranged in multidisciplinary focus areas

An interdisciplinary approach goes against good teaching practice where you develop a flow of ideas. An interdisciplinary approach goes against the way Science is actually practiced with skilled experts in their field contributing together with skilled experts in other fields.
I think some of these focus areas have merit.

The titles appear interdisciplinary, but the content is patchy at best...I can't see the point of moving away from the national content strands. Teaching and assessment make the difference between what is learned; curriculum describes the officially endorsed intended learning, whether it is described in the Australian or NSW versions of official curriculum documents. Support for implementation is the key to helping teachers deliver on those intentions.

Teachers/schools should be able to teach the content as best suits their students. It would be better if examples of interdisciplinary units of work were be suggested but not mandated (if that is indeed the case).

Science is multi-disciplinary by nature. However, there are certain skills and thought processes that are more inline with each discipline. If the multi-disciplinary approach is not done well then students may not experience this. Also, it is difficult for them to choose the single discipline subjects in year 11/12. The new stage 4/5 syllabus interdisciplinary focus areas are forced. They don't seem to follow a logical order or progression for student development.

Students find it easier to organise topics by discipline which aids in memory of content.

The reform states: ‘content has been arranged in multidisciplinary focus areas… to build a network of interrelated knowledge’. However, mixing up content from different branches of science and grouping them under a label such as ‘Change’ or ‘Water’ is forced and makes the progression from Stage 4 to Stage 5 work unclear. This will also create confusion when students choose senior subjects in Year 11. (Oddly, some units only represent a single branch of science).

Some interdisciplinary areas seem well thought-out while others are less content-focused and more skills-based, which may lead to inconsistencies in coverage between schools.

Appendix C

Origin and continuity of species

Syllabus component	**Comments** (excerpts from Australian Curriculum in blue)	**Suggested alternatives**
Origin and continuity of species	This phrase applies mainly to evolution. Students should know that this is the field of genetics	Some suggestions: Biology: Genetics and the continuity of species Genetics and evolutionary biology Genetics: molecular histories and futures Genetic:, variation, and change
Outcomes		
A student:		
applies the working scientifically processes to communicate scientific ideas and concepts using evidence	Working scientifically skills are how scientific ideas are developed, not how they are communicated. The suggested dot points in this focus area would not enable students to practise working scientifically skills.	Applies the working scientifically processes to generate, interpret and evaluate scientific evidence and communicate scientific concepts
assesses scientific evidence supporting the theory of evolution	Assess is a higher order verb than would be suggested by content descriptors. It is also unwise, as it implies there is a difficult decision to be made about the validity of the evidence for evolution. Assessing evidence for disputed topics is a good idea, but don't let evolution be seen as one of them. Any "assessing" of evolutionary evidence should be in relation to AC component "investigating the history and impact of developments in genetic knowledge"	Describes how the theory of evolution by natural selection explains the diversity of living things and is supported by a range of scientific evidence

explains how DNA has been used in genetic technologies to impact biodiversity	This doesn’t cover most of the genetics topic…Also, impacting biodiversity is not the intent of genetic technologies. DNA being "used" is also unusual phrasing. This outcome only covers one of many big ideas in genetics. Also, impacts on biodiversity not currently covered.	Explains how DNA and genes are responsible for the transmission of heritable characteristics and can be manipulated through genetic technologies.
selects and uses a range of media to process and represent data	Unlike the first outcome, this outcome is about how scientific ideas are communicated. But why mention just this skill? Especially in a unit that doesn’t include much data representation. Also, interpreting a range of media and representations of data is not mentioned here or elsewhere.	Selects and uses evidence from secondary sources to form evidence-based arguments about the impacts of developments in genetic knowledge

Content	**Examples**	**Comments**	**Suggested alternative phrasing/sequencing (based on AC, Duncan et al, 2009; Boerwinkel et al 2017)**
The theory of evolution and evidence by natural selection		Evidence *of* natural selection? Evolution topic needs to come after genetics topic (Todd et al. 2022) so students can refer to knowledge of genetic variation.	[move to end of focus area] · Explain how the processes of natural selection and isolation can lead to changes within and between populations and species · Investigate, using evidence from the fossil record, how the complexity and diversity of organisms has changed over geological timescales · Describe changes in Australian species over
Processes of natural selection including variation, isolation, and selection	Variation occurs through mutation, meiosis, fertilisation	None of these can come before genetics. Need to make sure these are covered well in the genetics topic	
The ways Aboriginal Peoples have observed evolutional changes in Australia	Various Aboriginal rock engravings and stories have depicted changes in plants and	the ways in which they observe it or the changes they observed? Evolutionary not evolutional	

	animals over time, such as megafauna.		timescales observed by Aboriginal peoples. · Discuss how scientific evidence was used to develop and refine the theory of evolution and the impact on understanding of the origins of species
How the complexity and biodiversity of organisms has increased over time	Use the geographic time scale to make observations and draw conclusions about how the complexity and biodiversity of organisms has changed over time.	meaningless without covering speciation. Note AC equivalent "describing biodiversity as a function of evolution" links better with outcome.	
Investigate, using secondary sources, the observations that led to the development of the theory of evolution	Anatomical similarities and differences, such as Galapágos tortoises and Darwin's finches, fossil observation, and the biogeographical distribution of plant and animal species (Wallace Line).	Not a good one to "investigate" as this is mainly only covered in textbooks.	
DNA structure and function		Function is crucial but missing from these dotpoints	
Observe chromosomes in the nucleus of cells undergoing cell division		There is no nucleus during cell division. Also, this is DNA in its most unusual form, it does not make for a good starting point for the mental model of genomes.	· Recall that all organisms have genetic information encoded in DNA molecules · Observe DNA and related structures using a variety of tools and techniques. For example, DNA extraction, prepared slides of cells undergoing division, molecular animations of chromosome organisation · Use models and diagrams to define and compare the terms gene, genome, DNA, and chromosome. · Relate the structure of the DNA double helix to its functions, including encoding instructions
Use models and diagrams to represent the relationship between genes, chromosomes and DNA in an organism's genome		need to add function here	
Model the Watson and Crick double helix structure of DNA	Showing the phosphate and sugar; the base pairing of A with T, and C with G.	It really doesn't need to be labelled "Watson and Crick" double helix. Keep the history separate to the biochemistry.	
Investigate how the work of Rosalind Franklin, and other scientists, contributed to, and		Leave Watson and Crick out of the dotpoint above and then put all of them in as examples here.	

validated, the double helix structure of DNA			for making proteins, stability and repair, and replication for growth and reproduction · Discuss the collaborative nature of scientific discovery by comparing the contributions of the scientists involved in the discovery of the double helix · Recognise that genetic information is passed on to offspring from both parents via gametes
Conduct an investigation to extract DNA	Banana, strawberry or kiwi fruit.	Guidance on making this an investigation? DNA extraction is just a single technique that can be used in an investigation (equivalent to saying "conduct an investigation to light a bunsen burner"). Otherwise just say "extract and observe DNA from plant tissue" Not a very satisfying investigation for students. Often quite disengaging.	
Genetics and mutations		Better title would be variation and inheritance. Genetics is too broad, and mutations is too narrow	
How DNA and genes are responsible for the transmission of heritable characteristics		This is a whole topic heading in AC. It covers the entire field of genetics, and yet still gives a very inadequate understanding of DNA and its role in encoding the proteins that are required for all biological processes (Haskel-Ittah and Yarden, 2018). Risks creating a false dichotomy between heritable and non-heritable characteristics, rather than acknowledging that almost all characteristics are the result of complex interactions between genes and environment.	· Explain how genetic variants can have beneficial, negative, or no effect on the functioning of an organism · Explain the role of proteins in connecting genes (genotypes) and traits (phenotypes), using both monogenic and multifactorial examples from plants and animals. eg height, colour (pigment production), cancer risk

		Supports misconception that DNA only involved in eyecolour, nose-shape etc.	· Examine evidence from whole genome sequencing to describe the amount of genetic variation between and within species · Identify causes of DNA mutation and possible outcomes including repair, cancer, and heritable genetic variation. · Use pedigrees and punnet squares to model simple (monogenic) gene-trait relationships and make predictions about patterns of inheritance (eg pea plant traits or recessive genetic conditions) · Consider applications of genetic testing and associated social, economic, and ethical implications (eg tracing ancestry, genetic counselling, population screening, or cancer treatment)
Compare the processes and products of mitosis and meiosis		not needed in stage 5. Need foundational knowledge that DNA is replicated in cell division, and that gametes carry one set of DNA to contribute to double set in offspring. Details of cell division processes not necessary (and are difficult to teach well)	
Mendelian inheritance can be used to predict the ratio of offspring genotypes and phenotypes in monohybrid crosses involving dominant and recessive alleles		this is good that it specifies that it can only be predictive in some circumstances but can easily be combined with the point below. Terminology is wrong, mendelian inheritance is the phenomenon not the methodology.	
Analyse models to predict inheritance patterns of simple dominant and recessive traits	Pedigree showing inheritance of traits, such as tongue rolling. Punnett squares showing inheritance of traits, such as pea plant traits.	Tongue rolling is not a monogenic trait. (nor are most human characteristics). Recessive genetic conditions could be studied in this way but would need different framing. Pedigrees and Punnett squares being “models” needs to be spelled out	
How mutations in the DNA sequence can lead to new variations and can have beneficial, negative, or no effect, on the functioning of the organism		Mutation needs to be discussed once genetic variation is already discussed, otherwise perpetuates misconception that there is a single "healthy genotype" with occasional deviations that create new phenotypes.	

Investigate how karyograms can be used to communicate information about chromosomal mutations	With the use of genetic counsellors.	This is the only reference to the genetic testing that will be commonplace in the medical care of the future. Karyograms are 1950s technology that are no longer used much in clinical practice (now replaced by chromosomal microarrays). What does "with the use of genetic counsellors" mean? Lots of hidden (yet important) syllabus content in that point. Unclear what is to be investigated here. Effects of chromosomal mutations? Genetic disease is not really introduced so a lot would need to be covered to do this well. AC phrasing is more appropriate "considering the use of genetic testing for decisions such as genetic counselling, embryo selection, identification of carriers of genetic mutations and the use of this information for personal use or by organisation such as insurance companies or medical facilities" as this describes the range of decisions likely to be faced by students in future.	
Genetic technologies			

Applications of genetic technologies can be used to produce therapeutic proteins such as hormones or medicines	Gene therapy, genetic engineering, biotechnology. – Adding genes into cells in place of missing or defective ones to correct genetic disorders.	Proteins not introduced elsewhere. Genetic technologies is a very broad term but production of therapeutic proteins is very specific, and has no connection at all to the gene therapies mentioned in the example.	· Relate the universal genetic code to the development of technologies using recombinant DNA · Identify examples of current and emerging genetic technologies including production of recombinant proteins and gene therapy · Investigate the role of bioinformatics and fast computing in genetic technologies · Compare applications of genetic technologies used in conservation, agriculture, industry, and medicine
Conduct a case study of Henrietta Lacks to create a written text discussing the ethical implications of the continued use of the HeLa stem cell line		Sudden introduction of an assignment outline? Specifying this in syllabus ensures ready availability of pre-written answers online. Suggest instead "use an ethics framework to create a written text discussing the ethical implications of a genetic technology" and give HeLa cells as an example.	
Use diagrams or simulations to investigate the steps involved in the process of gene therapy for treating genetic disorders	Cystic fibrosis or sickle-cell anemia.	genetic disorders are not covered. The details (steps) of genet therapy should be stage 6 content.	
Process and examples of genetic engineering	Genetic engineering is the artificial manipulation of DNA in order to modify an organism or population of organisms.	all other content in this section fulfils this. The terms "genetic technology", "biotechnology", "gene therapy" "recombinant DNA" and "genetic engineering" are overlapping in real life and are used inconsistently in syllabus.	
Using genetic technologies for conservation	Saving the white rhino from extinction. – Bleaching of coral in the Great Barrier Reef.	de-extinction is fringe science. Legitimate uses of genetic technology in conservation are mostly analytical techniques (eg whole genome sequencing.	

	– Bringing back extinct species, such as the Tasmanian tiger, woolly mammoth, dinosaurs.	Analytical genetic technologies are arguably even more relevant and important than recombinant DNA technologies. Bioinformatics and the big data revolution are also critical to mention alongside genetic technologies.	
Origin and continuity of species in context			
Investigate how recombinant DNA is used	Recombinant DNA is used in the production of golden rice, Bt-cotton, canola, production of insulin, hepatitis B vaccine.	many uses of recombinant DNA already covered. Could replace with investigating genetically modified crops and evaluating potential impact on biodiversity (as mentioned in the outcome for the focus area, which is currently not covered). Or use AC example and go broad: describing how scientific arguments, as well as ethical, economic and social arguments, are used to make decisions regarding personal and community issues	Use an ethical framework to construct evidence-based arguments about the implications of a genetic technology, (eg HeLa stem cell lines, CRISPR genetic engineering) (frameworks might include bioethical principles or stakeholder analysis)

Boerwinkel, D. J., Yarden, A., & Waarlo, A. J. (2017). Reaching a Consensus on the Definition of Genetic Literacy that Is Required from a Twenty-First-Century Citizen. *Science & Education*, *26*(10), 1087-1114. https://doi.org/10.1007/s11191-017-9934-y

Duncan, R. G., Rogat, A. D., & Yarden, A. (2009). A learning progression for deepening students' understandings of modern genetics across the 5th–10th grades. *Journal of Research in Science Teaching*, *46*(6), 655-674. https://doi.org/https://doi.org/10.1002/tea.20312

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Appendix C: Key Australian Research

STEM references based on Australian contexts.

Murphy, S. (2022). Science Education Success in a Rural Australian School: Practices and Arrangements Contributing to High Senior Science Enrolments and Achievement in an Isolated Rural School. *Res Sci Educ* **52**, 325–337. https://doi.org/10.1007/s11165-020-09947-5

Timms, M. J., Moyle, K., Weldon, P. R., & Mitchell, P. (2018). *Challenges in STEM learning in Australian schools: Literature and policy review*.Retrieved from https://research.acer.edu.au/policy_analysis_misc/28

Tytler, R., Osborne, J., Williams, G., Tytler, K., & Clark, J. (2008). *Opening up pathways: Engagement in STEM across the primary-secondary school transition*. Retrieved from https://www.voced.edu.au/content/ngv%3A52073

Tytler, R., Williams, G., Hobbs, L., Anderson, J. (2019). Challenges and Opportunities for a STEM Interdisciplinary Agenda. In B. Doig, J. Williams, D. Swanson, R. Borromeo Ferri, P., Drake, P (eds). *Interdisciplinary Mathematics Education*. ICME-13 Monographs. Springer, Cham.

Key principle	Application to the syllabus	Key reference
The curriculum should make it clear what the aims and purposes of science education are	The rationale and aims of the syllabus are vague. See Oftsed, 2019 for an example of explicit discussion of principles In research considering context-based curricula (e.g., PLON in the Netherlands,	Lijnse, P. L., Kortland, K., Eijkelhof, H. M., Genderen, D. V., & Hooymayers, H. P. (1990). A thematic physics curriculum: A balance between contradictory curriculum forces.*Science Education*, *74*(1), 95-103.

	Lijnsw et al., 1990), the authors explain that adjustments needed to be made to the curriculum to account for students wishing to study further (i.e., they required a change from the 'context-based' structure to having the concepts introduced first). A clear aim will allow the design of the curriculum to be much more validly informed by the literature (rather than drawing on a range of ideas, which are often not related and sometimes contradictory).	Ofted, 2019, Research review series: Sciencehttps://www.gov.uk/government/publications/research-review-series-science/research-review-series-science
Short term memory is limited and information is stored in long-term memory in 'schemas'	New material should not be introduced at a stage where it is too abstract/complex Material should be introduced in a way that facilitates schema building	Centre for Education Statistics and Evaluation. (2017). Cognitive load theory: Research that teachers really need to understand. https://education.nsw.gov.au/about-us/educational-data/cese/publications/literature-reviews/cognitive-load-theory Chi, M. T., Feltovich, P. J., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive science*, *5*(2), 121-152. St Clair-Thompson, H., Overton, T., & Botton, C. (2010). Information processing: A review of implications of Johnstone's model for science education. *Research in Science & Technological Education*, *28*(2), 131-148.
The curriculum should have a coherence that allows concepts to be introduced in a way that facilitates deep understanding	Science is a unique discipline with a unique epistemology and ontology. Scientific knowledge is created in specific ways, and scientific concepts have distinct structures. Scientific sub-disciplines are also unique from each other. The curriculum should make clear these distinctions. The curriculum should also be structured so as to introduce concepts in appropriate	Maton, K., Martin, J. R., & Doran, Y. J. (Eds.). (2021). *Teaching science: Knowledge, language, pedagogy*. Routledge. McPhail, G. (2021). The search for deep learning: A curriculum coherence model. *Journal of Curriculum Studies*, *53*(4), 420-434. Schmidt, W. H., Wang, H. C., & McKnight, C. C. (2005). Curriculum coherence: An examination of US mathematics and science content standards from an international perspective. *Journal of curriculum studies*, *37*(5), 525-559.

	ways. For instance, Schmidt et al (2005) analyse top performing schools' curricula to show that concepts are introduced gradually and are only in the curriculum for 2-3 years at a time (i.e., not all topics need to be included in all years/stages).	

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