LEARNING FIRST

Fixing the hole in Australian education

The Australian Curriculum benchmarked against the best

A note from the author

As CEO of Learning First, and in my previous roles at the Grattan Institute and the OECD, I have written many reports advocating for reforms in Australian school education. But I have never produced a report that expressed so much alarm about a fundamental aspect of our education system. I have never conducted analysis that showed such severe problems as those presented here. I take no joy in presenting these findings, but I am certain that the only way we can improve Australian education is to be honest about them. Problems not faced are problems not fixed.

This report sets out the results of detailed analysis and benchmarking of the Australian science curriculum with curriculums in comparable and high-performing systems around the world. The results show the lack of breadth and depth of the Australian science curriculum, the flaws in its sequencing of content, and the lack of clarity about what to teach and assess.

The benchmarking took over a year to complete, but in truth the report is the culmination of years of work. Many years ago, Learning First focused on school improvement, teacher and leader development and professional learning. As we worked with numerous Australian systems and published reports, we saw time and again that good policies and programs, and tireless work from educators, were not having the impact they should have.

The more we investigated the causes of these problems, the more we realised that a defining problem was curriculum: both the Australian Curriculum itself, and how it could be interpreted and effectively enacted in schools and classrooms. Many teachers, school and system leaders also expressed to us their deep concerns about the Australian Curriculum, yet significant curriculum reform is not part of Australia's policy debate. We are on a mission to change that.

About seven years ago we started publishing reports on the importance of curriculum, and to propose reforms to strengthen the Australian Curriculum in order to improve student performance and make our schools fairer and more equal. We have published reports with Johns Hopkins Institute for Education Policy in the United States, and we have written numerous opinion pieces on the need for change (read our work at www.learningfirst.com).

Throughout this work, what hit home was how different the Australian Curriculum is from quality curriculums in other systems, especially those that perform highly (or are improving) in international assessments. Whenever we show Australian teachers high-quality curriculums from other systems, they invariably have the same response: this content is so much clearer and would be so much easier to teach than the Australian Curriculum.

But how could we prove this point to a larger audience? Last year we decided to start benchmarking the content of the Australian science curriculum. Through the example of science, we wanted to show how the Australian Curriculum differs from the curriculums of leading systems around the world and how much improvement is needed. The results of this benchmarking are stark. Before starting the work, I knew there were problems with the Australian Curriculum but my colleagues and I have been shocked by the size of the holes in the Australian science curriculum revealed in this report.

I hope the report provides a way forward for Australian school systems and schools. I am convinced that we cannot significantly improve their learning outcomes or reduce the increasing inequality within Australian education without a fundamental overhaul of the Australian Curriculum.

Dr Ben Jensen, CEO Learning First

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The Australian Curriculum benchmarked against the best

By Ben Jensen, Mailie Ross, Michael Collett,
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November 2023

Jacqueline Magee, James Button and Hai-Chau Le and the team of science leaders and teachers that undertook and verified the benchmarking all made significant contributions to this report.

Learning First is an education research and consulting group that works closely with schools and systems in various countries to improve educational equity and student learning. We draw lessons from leading research and the practical experience of high-performing systems around the world. Over the years, we have worked with federal, provincial and district leaders in numerous countries, and with every state and territory government in Australia. We have published numerous research reports and conducted research and advisory work for global organisations such as the OECD, the Bill and Melinda Gates Foundation and the National Centre on Education and the Economy in the United States.

Overview

Every year brings new evidence of decline in Australian school education: sliding performance and increasing inequality on international and national assessments.[1] More than a decade of school improvement and teacher development programs, literacy and numeracy strategies and other initiatives has failed to reverse the fall in results.

These deeply disturbing trends have many causes, but this report argues that a fundamental cause of Australia's education decline is the Australian Curriculum.

Learning First has conducted the first detailed benchmarking of the content of the Australian science curriculum against seven high-performing and comparable systems around the world. This benchmarking shows that compared with the curriculums of these systems, the Australian science curriculum sets a low standard for what students should learn. It lacks the content, depth and breadth to enable them to succeed.

Our benchmarking shows that the Australian science curriculum in the first nine years of schooling:

- Contains about half the science content of the average of other curriculums
- Lacks breadth of learning: it covers 44 science topics compared to an average of 74 topics in other systems
- Lacks depth of learning: just five science topics are covered in depth compared to an average of 22 topics covered in depth in other systems

The Australian science curriculum also contains poor sequencing and lack of specificity of content, which the research shows is vital for effective teaching and learning.

Curriculum experts often describe breadth and depth of content in a curriculum as trade-offs; should more time be spent going deeper into certain topics or should more topics be covered but in less depth?[2] Sadly, the Australian science curriculum lacks both breadth and depth. It covers fewer topics and goes into depth in these topics far less often than other benchmarked curriculums. A narrow and shallow curriculum has damaging consequences for both learning and equity.

Since the Australian Curriculum was released in 2010, the performance of students in international OECD PISA science assessments has fallen by almost a whole year of schooling.[3] Assigning blame directly to the curriculum is not possible, but the question must be asked: what would people expect to be the impact on student learning and equity if one school system was provided with a curriculum that contained half the content of others?

Instead of recognising these problems, whenever poor results are published, teachers are often explicitly or implicitly blamed. But in the light of our curriculum problem, Australian teachers have done an extraordinary job to not let the standards of students fall further than they have.

There is no reason Australia cannot have a world-class curriculum, as other systems do. The key is a new system of curriculum development, built on the latest research on quality curriculum. The curriculum's content, sequencing and breadth and depth of topics all need to be comprehensively benchmarked. We need to respond to data on how the curriculum is taught across schools and classrooms (what is working

[1] See for example: Australian Government, 2023; OECD, 2019
[2] See, for example: Black 1995; William H Schmidt et al. 1997
[3] Organisation for Economic Cooperation and Development (OECD) Programme for International Student Assessment (PISA) 2018 Country Note: Australia.

and not working), and we need a new, explicit focus on inequality that ensures *every* Australian student has the right to learn a world-class curriculum.

This report focuses on the Australian science curriculum. We have not yet benchmarked other subjects in the Australian Curriculum. If all other parts of the Australian Curriculum have been developed with comprehensive benchmarking, quality research, and analysis of what is taught and assessed in schools then we call on the Australian Curriculum, Assessment and Reporting Authority (ACARA) to release this information. If it does not exist, we recommend an overhaul of the entire Australian Curriculum.

A way forward: recommendations for change

With the right processes in place, a quality world-class curriculum can be achieved for Australian students. The following steps set out a tangible pathway. Curriculum leaders should:

1. Commit to an overhaul of the Australian Curriculum. A few minor amendments will not fix the problems with the lack of content and breadth and depth of topics covered, and with poor sequencing. A complete rewriting is essential.
2. Lead curriculum reform and public debate with a focus on the detail of what is taught and assessed in classrooms. The high-level slogans and sound bites of Australian Curriculum debate pull the curriculum further from the realities of what happens in classrooms, and make it harder to teach effectively
3. Adopt a new development *process* that ensures a world-class Australian Curriculum. All future versions should be built on:
    a. A comprehensive research program on quality curriculum and what is required to improve learning of ***all*** students
    b. Comprehensive benchmarking of detailed curriculum content, including breadth and depth of topics, to ensure the curriculum is world-class
    c. Detailed curriculum mapping to ensure effective sequencing of curriculum content
    d. Detailed comparative analysis of curriculum structure, presentation and writing of the curriculum to ensure it is clearer and easier to teach
    e. Data and analysis of how the curriculum is being implemented in schools and classrooms and how much work school leaders and teachers have to do to implement it.
4. Establish a clear and public curriculum entitlement that guarantees all Australian students the right to learn curriculum content that is as strong as the curriculum entitlement provided to students in other systems.

Curriculum reform always causes disruption and additional work in schools. This is a difficult time in Australian schools with teacher shortages and heavy workload pressures. Our call to overhaul the curriculum is therefore not taken lightly. Disruption to schools must be minimised. The roll-out of the latest version of the Australian Curriculum, already underway in some states and territories, may have to be halted until the work is done to create a truly world-class curriculum. On balance, it is better to bite the bullet and spend the next few years developing a truly world-class curriculum before imposing the cost and time of its implementation on schools.

The proposal set out in this report is neither far-fetched nor unachievable. But because the development of the Australian Curriculum has fallen so far behind best practice, significant reforms are required. Only with these changes can we establish what educators call the curriculum entitlement provided to all students, a commitment to young people that is a foundation of high performance and equity in leading education systems around the world.

Table of Contents

Overview 3
1 What is a curriculum and why is it so important? 6
2 The lack of content in the Australian science curriculum 13
3 Failing on breadth and depth 20
4 Poor sequencing and lack of specificity in the Australian Curriculum 25
5 Problems with optional content 30
6 How to solve the problems with the Australian Curriculum 33
7 References 35
8 Annex A: Methodology: How did we undertake science curriculum benchmarking? 37

1 What is a curriculum and why is it so important?

A curriculum is the foundation of an education system, providing the guaranteed learning entitlement for all students. To quote the Australian Curriculum, Assessment and Reporting Authority (ACARA), the body responsible for developing the Australian Curriculum: [4]

'*The Australian Curriculum describes to teachers, parents, students and others in the wider community what is to be taught and the quality of learning expected of young people as they progress through school*.'

A quality curriculum is rigorous, setting high expectations for student learning; it is clear and specific about what students are to learn; the domains, topics and specific content within each topic that needs to be taught at each year level.[5] It is cumulative, with content sequenced across year levels, so that student learning effectively builds on prior learning.[6] It must prepare students for ongoing education within and beyond school. Finally, a quality curriculum should be well-rounded, providing breadth and depth of learning experiences across all areas of the curriculum.[7]

A system curriculum drives what is taught and assessed in schools and classrooms. Curriculum research distinguishes between the impact of a system curriculum and the impact of what is taught and assessed in classrooms.[8] Much of the latter has shown significant increases in learning and equity can occur when high-quality, comprehensive curriculum resources are used in schools.[9]

Research at the system level has shown that high-quality reforms to a system curriculum can improve performance and equity and that the opposite can occur with low-quality curriculum reform.[10]

Figure 1 presents a simplified illustrative example of how a system curriculum like the Australian Curriculum impacts what is taught and assessed in schools and classrooms. As discussed above, a system curriculum details 'what is to be taught and the quality of learning expected of young people as they progress through school.'[11] It sets the content to be taught, the sequencing of content, and the learning expectations across schooling. A curriculum can also support effective pedagogy, assessment and learning experiences.

In schools, teachers and school leaders take the curriculum and make numerous decisions on how to enact it in their schools and classrooms. They develop curriculum plans at multiple levels of the school, they develop assessment schedules and individual assessments, unit and lesson plans, along with a host of curriculum and instructional materials to use in classrooms. School leaders and teachers develop many of these themselves and purchase others.

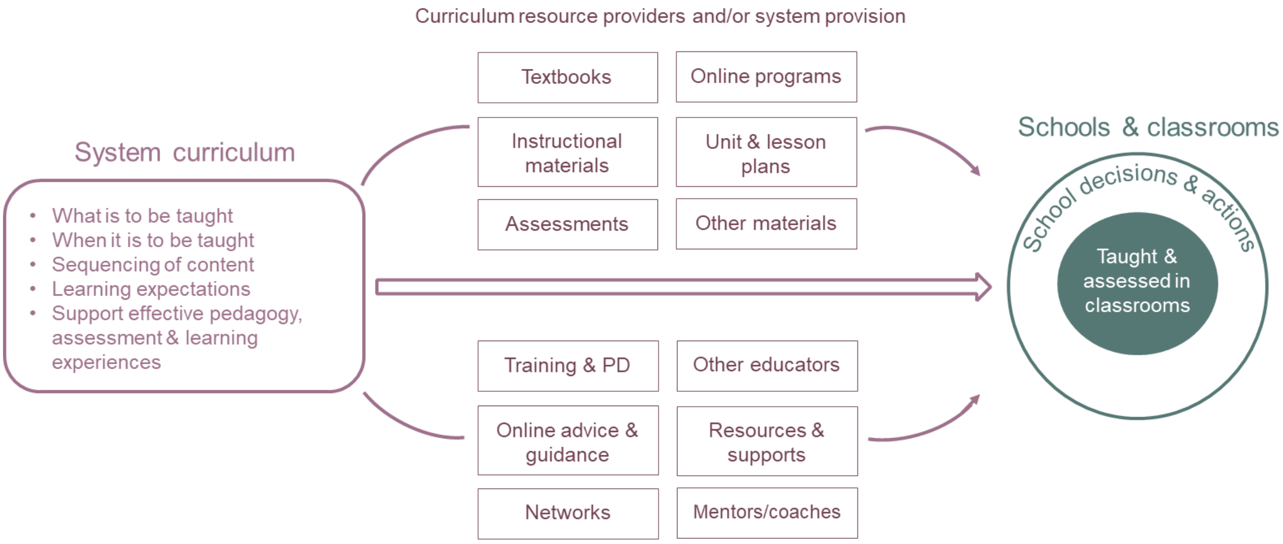
The curriculum they use shapes all this work. The unit and lesson plans that teachers make have goals linked to the standards in the curriculum, they cover content in the curriculum, and their assessments are based on the content, standards and broader expectations set by the curriculum.

[4] Australian Curriculum Assessment and Reporting Authority 2020.
[5] Berner 2018; Common Core 2009; Hirsch 2016; Houchens 2017; Magee and Jensen 2018a, 2018b; Steiner, Magee, and Jensen 2018, 2019.
[6] Large significant impacts have been found when rigorous quality curriculum is used in multiple years in students' education creating a large cumulative impact: Hirschhorn 1993; What Works Clearinghouse 2016; Willingham 2019.
[7] Steiner et al. 2018.
[8] Educators will often use the terminology of the documented (system) curriculum and the enacted curriculum (in schools and classrooms) when discussing this distinction.
[9] Hunter, Haywood, and Parkinson 2022. See also, for example: Lynch et al. 2019; Stokes et al. 2018; Taylor et al. 2015: Borman, Dowling, and Schneck 2008.
[10] Common Core 2009; Crato 2019, 2020; Hirsch 2016; Steiner et al. 2018.
[11] Australian Curriculum Assessment and Reporting Authority 2020.

Most schools and their teachers are required to teach the curriculum. A high-quality curriculum can effectively support this work, while a low-quality curriculum that is lacking in content, has poor sequencing, and poor learning expectations has obvious impacts on this work.

Often, school leaders and teachers will directly implement what is laid out in the curriculum. But school leaders and teachers work in a broader system that includes many players. The latter offer guidance, professional development, and curriculum and instructional materials, among other supports. Sometimes these are offered by private providers (for example, companies that sell textbooks), sometimes by government or system leaders, and often by other educators, mentors and coaches offering support.

Figure 1: Illustrative example of how a system curriculum impacts what is taught and assessed in schools and classrooms



Again, the curriculum impacts the quality of what is offered to school leaders and teachers. A number of systems around the world have evaluated the quality of resources offered to schools. A key measure of quality is always alignment with the curriculum: does a resource include content in the curriculum, is it sequenced in the same way as the curriculum, does it provide learning experiences that create the same expectations as does the curriculum, and so on. In this way, the strengths and weaknesses of the curriculum are passed on to schools through the resources offered to schools

All these school processes reflect the distinction in the research between the impact of what is taught and assessed in schools – often with a focus on the quality of the curriculum resources used in classrooms – and the system-level impact of a curriculum. Both have an impact, and both are strongly connected.

To reform a curriculum, we need to understand these connections. What is most important for this report is how the strengths and weakness of the curriculum flow through the system and impact what is taught and assessed in classrooms. This is why the research shows not only the impact of what is taught and assessed in schools, but also the changes to learning and equity following changes to a system curriculum.[12]

What has happened to performance since the Australian Curriculum was introduced?

Figure 2 presents the science scores of Australian students in the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA), taken by students

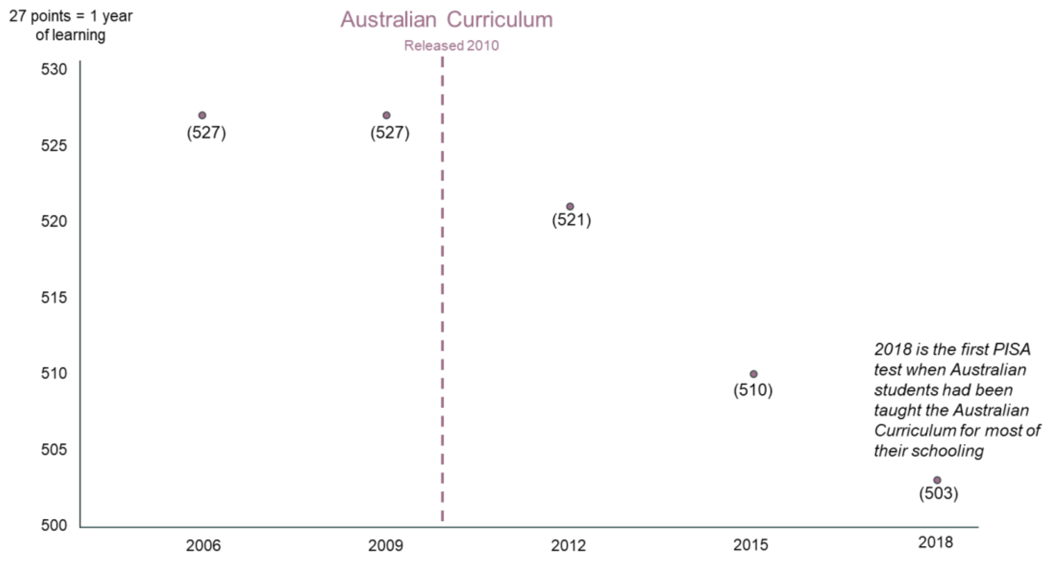
[12] Common Core 2009; Crato 2019, 2020; Hirsch 2016; Steiner et al. 2018.

around the world every three years. As the figure shows, the performance of Australian 15-year-olds was high and steady in 2006 and 2009. But since the release of the Australian Curriculum in 2010, the performance of students has steadily declined.

By 2018, Australia's average science scores had fallen by 24 points, equivalent to nearly a full year of schooling. In other words, Australian students who were 15-years old in 2018 – who have spent most of their schooling studying the Australian Curriculum – performed at a level nearly a year below the level of their peers in 2009 before that curriculum was introduced. During this period, a growing number of systems around the world leapfrogged Australian students in performance on PISA.

This decline cannot be blamed directly on the Australian Curriculum – the complexity of education systems makes it impossible to apply causality to a single initiative. Nevertheless, it is vital to consider the impact of giving one school system a curriculum with half the content of other systems. A curriculum that did not include important topics or included them at only a low level of content. What changes in learning outcomes and in equity would we expect over the subsequent decade?

Figure 2: PISA science scores before and after the Australian Curriculum



Source: OECD: Programme for International Student Assessment (PISA) 2018 Country Note: Australia

Instead of recognising the problems with the Australian Curriculum, when poor results are published the finger is often pointed – either explicitly or implicitly – at teachers and teacher quality. This blame-game ignores the curriculum problem in Australian education. In light of it, Australian teachers have done an incredible job to not let the standards of Australian students fall further than they have.

For too long, Australian science teachers have been asked to succeed in spite of the Australian science curriculum. Instead of enacting a world-class curriculum, Australian science teachers are required to work with a curriculum lacking content, breadth and depth and poor sequencing. When it all goes wrong in schools it is teachers who have to deal with the problems. And we have let teachers cop great criticism for what is a deep system failure. Australian teachers, as well as students deserve the world-class curriculum that other teachers around the world can rely on.

Curriculum and education reform is complex. Improving the Australian Curriculum will not immediately solve all Australia's education problems. To achieve significant change in equity and education outcomes requires a world-class curriculum that is then implemented in schools with integrity. In turn, this requires multiple resources, supports, training and professional development.

Nevertheless, the Australian Curriculum is the engine of school learning, placing floors and ceilings on the effectiveness of so many decisions and actions that impact learning and equity. Australian systems have spent so much money on curriculum resources and supports, professional development and training and other programs. Unfortunately, a lot of the impact of these investments depends on the quality of the Australian Curriculum.

1.1 How we benchmarked the science curriculums

A curriculum is the foundation of an education system, providing the guaranteed learning entitlement for all students. To quote ACARA, the body responsible for developing the Australian Curriculum:

'*The Australian Curriculum describes to teachers, parents, students and others in the wider community what is to be taught and the quality of learning expected of young people as they progress through school*.'

Learning First benchmarked the Australian science curriculum by comparing the content of what the curriculum says is to be taught at each year level with content from the science curriculums of seven other systems: Alberta (Canada), Quebec (Canada), Singapore, England, the United States, Hong Kong and Japan.

Different curriculums present content – what is to be taught – in different ways. For example, the Australian science curriculum consists of three strands (Science understanding, Science as a human endeavour and Science inquiry) and includes:

- **Achievement standards** for each learning area or subject that describe the learning expected of students at each year level or band of years.
- **Content descriptions** that describe what is to be taught and what students are expected to learn.
- **Optional content elaborations** that give teachers ideas about how they might teach the content.

In contrast, the Hong Kong science curriculum for Years 7-9 is divided into thematic units, and the content is presented in three categories:

- Students should learn
- Students should be able to
- Suggested learning and teaching activities.

Benchmarking does not make a judgement about which structure is best, but instead compares the level of content in different curriculums. It is possible to have lots of words on a page but not much content and vice versa.

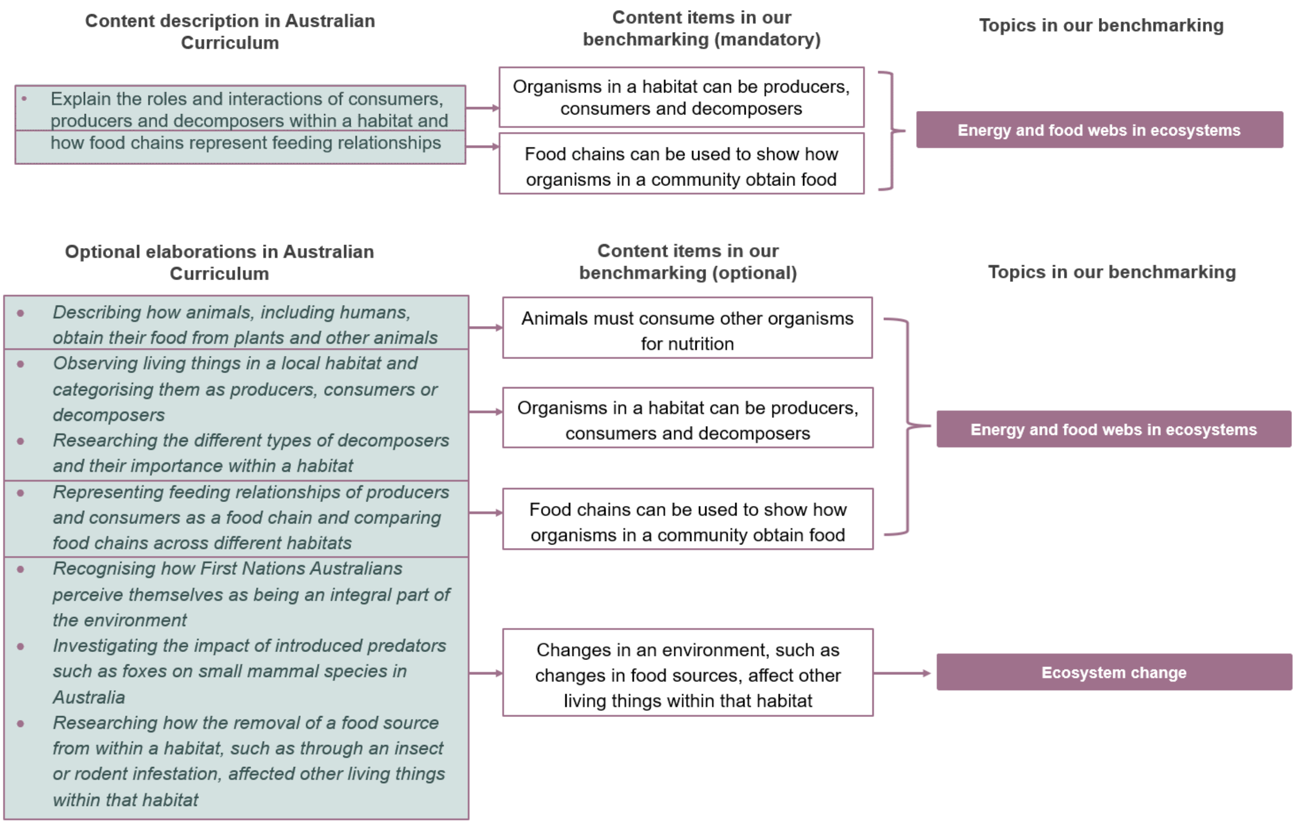
Learning First analysed the content in each curriculum in order to identify the individual pieces of scientific knowledge within each curriculum document. Each piece of scientific knowledge was coded as an individual content 'item'. One item of content represents one piece of scientific knowledge – for example, 'the cell is the basic unit of life' – that students are expected to learn. Every content item was identified as either mandatory or optional to teach.

Learning First did not start with a universal list of content items and then check which curriculums did or did not include them. Rather, we identified discrete pieces of scientific knowledge in all the curriculums analysed for this report, coded them as content items, and cross-referenced them against every other curriculum to determine whether they existed in other systems' science content.

After a database of content items was developed for all systems included in the analysis, content items were then sorted into topics. A topic is a disciplinary area of knowledge made up of closely related content items.

To illustrate the coding process, let's consider the Australian Curriculum's Year 4 biological sciences content description: '*explain the roles and interactions of consumers, producers and decomposers within a habitat and how food chains represent feeding relationships*'. Our benchmarking shows that this content description forms two unique content items, contributing to one topic (Energy and food webs in ecosystems) within our benchmarking database. In addition, the optional elaborations have been coded as four optional content items (two of which were not present in the content description), contributing to an additional topic (Ecosystem change). Figure 3 shows this process.

Figure 3: Illustration of our benchmarking process



Each topic was then sorted into a domain, using the sub-strands within the 'Science understanding' strand of the Australian Curriculum. These four sub-strands, and hence the four domains used for this benchmarking, are biological sciences, Earth and space sciences, physical sciences and chemical sciences[13].

In order to confirm the content items, topics and domains for all systems benchmarked, we undertook multiple rounds of validation of the database by curriculum experts, data analysts and current and former science teachers who collectively have studied each domain at a tertiary level. Once we had established

[13] These domains are referred to differently across systems. For example, biological sciences is sometimes referred to as life sciences.

and validated the database to represent the benchmarked curriculums as individual items of content sorted into topics and domains, we could then make comparisons between systems.

The total number of topics and items of content under each domain across all curriculums were:

	Biological sciences	Chemical sciences	Physical sciences	Earth and space sciences
Topics	35	28	29	27
Items of content	362	243	349	253

To illustrate, the chemical sciences domain comprised 28 topics:

- Acids and bases
- Atomic theory
- Chemical bonding
- Chemical change
- Chemical formulas and equations
- Chemical reactions
- Combustion
- Concentration and solutions
- Displacement reactions
- Electrochemistry
- Electronic structure and valency
- Elements and compounds
- Hydrocarbons
- Mass, volume and density
- Materials
- Material properties
- Metals
- Neutralisation reactions
- Particle model
- Periodic table of elements
- Physical change
- Pure and impure substances
- Radioactive decay and fusion
- Rate of reaction
- Solubility
- States of matter
- Synthesis and decomposition reactions
- Thermal expansion

Among these topics, the particle model topic contained 12 items of content:

- All matter is made of tiny particles.
- Attractive forces are strongest in solids.
- Attractive forces are weakest in gases.
- Gas particles move randomly (Brownian motion).
- Particles in gases are separated by large spaces.
- Particles in liquids are able to slide over each-other.
- Particles in solids are close together and vibrate.
- Particles of matter are in constant motion.
- The speed and distance between particles increases with temperature.
- The speed of particles changes with heat and explains changes of state.
- There are attractive forces between particles.
- There is empty space between particles.

How were systems included in the benchmarking compared?

Benchmarking for this report compared the Australian science curriculum for Foundation to Year 10 (F-10) with the science curriculums of Alberta (Canada), Quebec (Canada), Singapore, England, the United States, Hong Kong and Japan. The Victorian science curriculum F-10 and draft NSW science curriculum 7-10[14] were also benchmarked.

[14] We benchmarked the new Year 7-10 draft science curriculum for New South Wales as the primary school science curriculum was not yet available.

In this report, curriculum levels of instruction for all systems are referred to as 'years' to align with how the Australian Curriculum represents the different stages of learning. However, not all curriculums formally use this language to represent each level. For example, what the Australian Curriculum calls Year 1, the United States calls First Grade.

It was not possible to compare the exact same number of years of instruction across each system. Students in Australia, Alberta and the United States begin studying science in their Foundation year. In England, Hong Kong and Quebec, science starts in Year 1; in Japan and Singapore, in Year 3.

Where possible, curriculums were benchmarked up to Year 10. For some systems, this was not possible because the curriculum was not available past a certain year level, or because the science curriculum becomes specialised beyond Years 8-9 (for example, it contains a specialist chemistry subject). This is why the majority of comparisons in this report focus on curriculums from Foundation to Year 8. However, because England presents Years 7-9 content as a single stage, content was coded up to Year 9, rather than Year 8. The full methodology can be found in Annex A.

Why benchmark science?

Science was chosen as a subject that lends itself to this form of benchmarking: chemistry is more consistently taught across the world than, for example, Australian history. Moreover, science content can be identified and categorised in a manner that enables benchmarking. The task would be much harder for English or literature, for example.

In addition, it is widely considered that Australia has critical shortages in the science and technology workforce; areas that are critical for modern economies and societies. In 2022, the Australian Government announced a commitment to widen the pipeline of talent available to the science and technology sectors and address 'a decade long science and tech skills shortage.'[15] Last year, Engineers Australia called on the Australian Government to invest in an engineering pipeline strategy to address 'plummeting rates of secondary students taking up STEM (science, technology, engineering, maths) subjects [that] is setting the nation up to fail as it transitions to a smart jobs economy.'[16]

[15] See the Minister for Industry and Science 'Paving a pathway for a diverse science and tech workforce', 6 September 2022. Accessed at: https://www.minister.industry.gov.au/ministers/husic/media-releases/paving-pathway-diverse-science-and-tech-workforce.
[16] Engineers Australia, 2022. Accessed at: https://www.engineersaustralia.org.au/news-and-media/2022/07/media-release-new-report-shows-alarming-stem-skill-shortage-threatens-new.

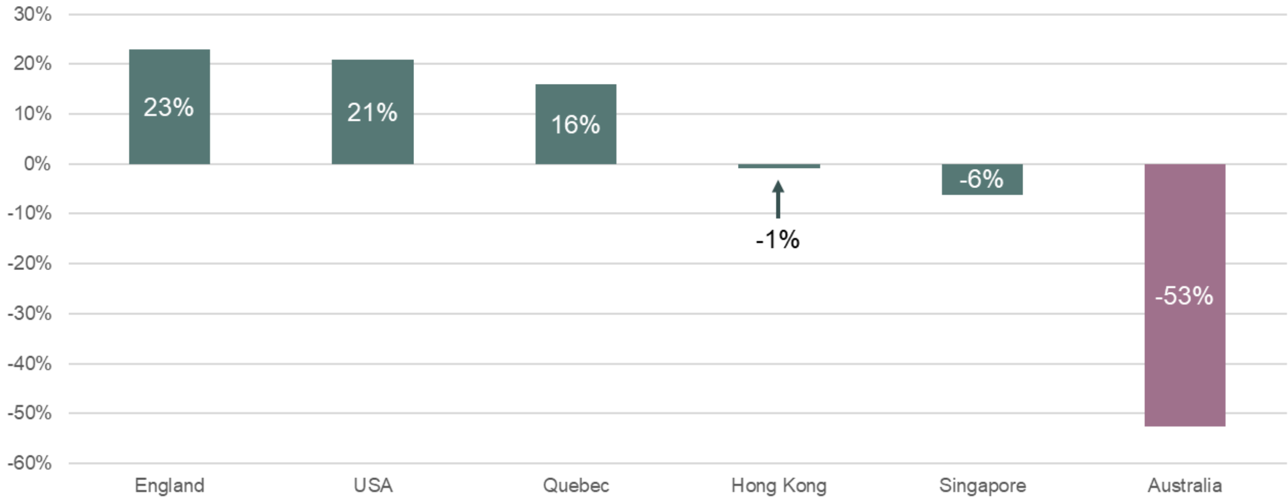
2 The lack of content in the Australian science curriculum

The volume of content included in a curriculum, the sequence and timing of when students should learn that content, and the breadth and depth of topics covered, are all important markers of the quality of the learning expected of students. Curriculum content sets out the guaranteed learning entitlement for students; in other words, what they should know and be able to do as a result of their schooling.

The Australian Curriculum includes much less science content than does every other curriculum benchmarked in this report. A gap between Australia and other systems begins to emerge at primary school, and it grows year on year. By Year 8, the lack of content in the Australian science curriculum is so great that it has only about half of the average content of the other benchmarked curriculums. In terms of the volume of content in its science curriculum, Australia is an outlier.

Figure 4 compares the amount of content included in the curriculums of six benchmarked systems from the first year of school to the end of Year 8.[17] By the time students in Australia finish Year 8, they will have covered less than half as much content as every other system in this chart.

Figure 4: Percentage of content included in system curriculums compared to the average, from Foundation to Year 8



Note: Amount of content is defined as number of mandatory items of content. Content that is optional is not included in this data. This figure compares cumulative coverage but does not compare the same number of years of instruction. Australia and the United States commence science in the Foundation year. In England, Quebec and Hong Kong, science starts in Year 1. In Singapore, science starts in Year 3. England presents Years 7-9 content as a single stage, so this figure includes England's content up to Year 9; however, English students in Year 9 are the age-equivalent of Australian students in Year 8. See methodology for more detail.

[17] Secondary school science curriculums cannot be benchmarked for all years of secondary school. The Australian Curriculum defines science content up to Year 10, but benchmarking was not possible in all systems up to Year 10. This was because some systems have specialist subjects, for example, chemistry subjects rather than broader science subjects. It would not be fair to benchmark the amount of, for example, chemistry content in a specialised chemistry subject in Singapore to a general science subject in Australia. Benchmarking has therefore only included general science subjects.

Alberta and Japan

Alberta and Japan have not been included in the above figure, since only primary school curriculum content has been benchmarked for these systems. It is notable, nevertheless, that Alberta has more than two and a half times more content in its primary school science curriculum than the Australian Curriculum has in its first nine years. In Japan's primary school curriculum, science does not begin until Year 3. But our benchmarking shows that even in four years, Japan's science curriculum has about the same volume of science content as the Australian Curriculum has in nine years.

If we analyse different years of schooling, the benchmarking shows that the Australian science curriculum contains:

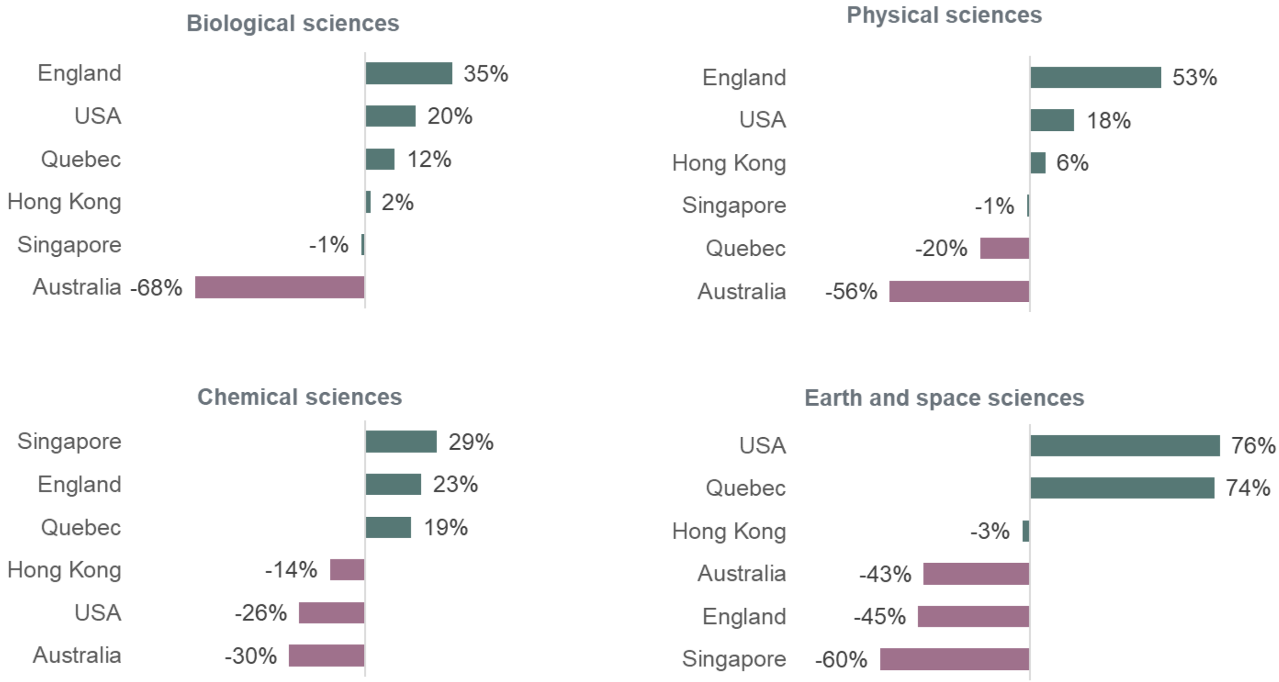
- 45 per cent less content that the average of the primary school science curriculums of Alberta, Quebec, the United States, Japan, Singapore, England and Hong Kong
- 59 per cent less content between Years 7-10 than the average of the secondary school science curriculums of Hong Kong and England (Years 7-9) and of Quebec (Years 7-10)
- 20 per cent less science content in four years of secondary school than the Singapore science curriculum has in just Years 7-8
- 70 per cent less content than the Quebec science curriculum in Years 7-10.

2.1.1 Differences across science domains

Figure 5 compares science learning by the four science domains: biological, physical, chemical and Earth and space sciences. It shows differences in content in the curriculums of six benchmarked systems, against the average, from Foundation to Year 8. The data show no consistent pattern but instead considerable variation in how each curriculum covers content in each domain.

In biological sciences, Australia includes nearly 70 per cent less content compared with the average – the largest gap of any science domain. Australia performs relatively better in chemical sciences, where it has just under a third less content than the average of other systems. In physical sciences and Earth and space sciences, Australia has 56 per cent and 43 per cent less content respectively than the average of other systems.

Figure 5: Percentage of content included in systems' curriculums compared to the average, from Foundation to Year 8, by domain



Note: Amount of content is defined as number of mandatory items of content. Content that is optional is not included in this data. Each domain does not contain the same amount of content. This figure compares cumulative coverage but does not compare the same number of years of instruction. Australia and the United States commence science in the Foundation year. In England, Quebec and Hong Kong, science starts in Year 1. In Singapore, science starts in Year 3. England presents Years 7-9 content as a single stage, so this figure includes England's content up to Year 9; however, English students in Year 9 are the age-equivalent of Australian students in Year 8. Physical sciences often refers to an overarching domain including physics, chemistry and Earth sciences; here, it is the term used in the Australian Curriculum to refer to physics only. See methodology for more detail.

Another way to look at these data is to consider what they mean for the learning opportunities of Australian students. Compared with the Australian science curriculum:

- The United States science curriculum has nearly four times the amount of biological sciences content and two and a half times the amount of physical sciences content
- The Quebec science curriculum has three times the amount of Earth and space sciences content.

A further problem is that the Australian Curriculum introduces some topics years later than do other curriculums. In the Australian science curriculum:

- Evolution is taught in Year 10 compared with Years 5-6 in Quebec and Year 6 in England
- Acids and Bases is taught as optional content in Year 10 compared with Year 6 in Japan, Year 8 in Hong Kong and Years 7-8 in Quebec and Singapore.

Some might assume that the Australian Curriculum presents these topics later because it goes deeper into the content. But that is not correct. For example, the Australian Curriculum introduces evolution only in Year 10, when it states: '*use the Theory of Evolution by natural selection to explain past and present diversity and analyse the scientific evidence supporting the theory*'.

By contrast, England's science curriculum at Year 6 introduces the topic of evolution and states that students should be able to:

- recognise that living things have changed over time and that fossils provide information about living things that inhabited the Earth millions of years ago
- recognise that living things produce offspring of the same kind, but normally offspring vary and are not identical to their parents
- identify how animals and plants are adapted to suit their environment in different ways and that adaptation may lead to evolution.

England's curriculum then builds on the content for evolution in Years 7-9.

Similarly, the topic of acids and bases is referenced only in an optional elaboration in Year 10 of the Australian science curriculum.

By contrast, the Singapore curriculum introduces comparison of acids and bases in Years 7-8, two to three years before the Australian Curriculum does. The Singapore science curriculum clearly states the content as:

- the chemical reactions between acids and alkalis
- the effect of acidic, alkaline and neutral solutions on indicators (include litmus paper, Universal Indicator and natural indicators obtained from plants)
- the chemical changes that matter (i.e. element, compound or mixture) undergoes upon mixing (e.g., neutralisation).

This comparison shows less depth of content in the Australian Curriculum, even though this topic is taught two to three years later than it is in Singapore.

How much content?

Curriculum development is not a race to include the most content, and no curriculum has a perfect amount. Benchmarking provides useful information to compare curriculums: the amount of content covered, the breadth and depth of topics to ensure that a curriculum can be considered world-class, what opportunities students get to learn important content compared with their peers in other systems. A future Learning First report will highlight lessons from this benchmarking for curriculum designers seeking to develop a world-class curriculum with the most breadth, depth and clear sequencing of content.

2.2 Science skills

Science skills are an important part of any curriculum. These skills, are described in different ways in different curriculums but they usually reflect the scientific method: the ability to generate, test, and evaluate claims, data, and theories.[18]

Our analysis shows that each benchmarked curriculum includes science skills and sees them as important components of teaching and learning. Table 1 shows how Australia, England, the United States, and Singapore categorise science skills in similar ways.

[18] For example, see: Bullock, Sodian, and Koerber 2009.

Table 1: Examples of science skills included within different curriculums

Australia (Years F-10)	England (Years 7-9)	The United States (Years K-8)	Singapore (Years 7-8)
Science inquiry	**Working scientifically**	**Science and engineering practices**	**Demonstrating ways of thinking and doing in science**
• Questioning and predicting • Planning and conducting • Processing, modelling and analysing • Evaluating • Communicating	• Scientific attitudes • Experimental skills and investigations • Analysis and evaluation • Measurement	• Asking questions and defining problems • Planning and carrying out investigations • Developing and using models • Analysing and interpreting data • Constructing explanations and designing solutions • Engaging in argument from evidence • Obtaining, evaluating, and communicating information	• Investigating • Evaluating and reasoning • Developing explanations and solutions

Note: This table provides examples of the types of science skills included in each curriculum. More detail on each science skill is provided in the curriculum documentation in each system. The United States also introduces the skill 'Using mathematics and computational thinking' from Year 5.

Curriculums differ significantly in how they present science skills. The Australian Curriculum makes generic statements about them, presents them separately from content and requires teachers to teach them each year. Other systems stipulate that science skills should be taught alongside specific content or in specific learning experiences.

As students move from one year level to the next, the complexity of skills increases but the skills are isolated from science content. Table 2 below shows how both the Australian Curriculum and England's national curriculum present science skills as generic statements.

It should be noted that the Australian Curriculum does include some optional elaborations on how a teacher can pair the skills with content. For example, optional elaborations within the Science Inquiry strand will occasionally refer to specific content or example activities. An optional elaboration, in Year 7, identifies '*assumptions relating to variables that are assumed to be constant, such as ambient temperature, properties of materials used or purity of substances'.*

In addition, optional elaborations within the Science understanding strand also occasionally reference specific activities or experiments that students can undertake. For example, two optional elaborations related to science skills in Year 7 are:

- Using provided dichotomous keys to identify organisms surveyed on a field trip
- Investigating and using a range of physical separation techniques such as filtration, decantation, evaporation, crystallisation, chromatography and distillation.

Table 2: Examples of generic science skills in the science curriculums of Australia and England

Examples of science skills written as generic statements
Australian Curriculum (Year 7)
Planning and conducting (a sub-strand of the Science inquiry strand) • Plan and conduct reproducible investigations to answer questions and test hypotheses, including identifying variables and assumptions and, as appropriate, recognising and managing risks, considering ethical issues and recognising key considerations regarding heritage sites and artefacts on Country/Place
England (Years 7-9)
Experimental skills and investigations (a sub-strand of the Working scientifically strand) • Select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate

In contrast to Australia and England, some curriculums present science skills *alongside* science content in specific year levels or stages. In the United States and Singapore, science skills describe specific activities, experiments and investigations students should undertake when learning specific content. Table 3 provides examples of how both the United States and Singapore curriculums pair science skills with content.

Table 3: Examples of specific science skills in the United States and Singapore

Examples of specific science skills
The United States (Years 6-8)
Planning and carrying out investigations (a sub-strand of the Science and engineering practice strand, presented with content on forces and interactions) • Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim. • *Students who demonstrate understanding can*: Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
Singapore (Years 7-8)
Investigating (a sub-strand of the Demonstrating ways of thinking and doing in science strand, presented with content on physical properties and chemical composition of matter) • investigate the separation of constituents of mixtures based on basic principles involved in the following separation techniques: ○ magnetic attraction ○ filtration ○ evaporation ○ distillation ○ paper chromatography.

The science skills discussed above cannot be benchmarked in the same way as content in the domains and topics taught in a science curriculum. That is in part because curriculums don't quantify how often science skills should be applied in teaching a domain or topic. Instead, our report analysed which science skills are included in each curriculum and whether they are included alongside or separate to specific content.

3 Failing on breadth and depth

An important part of benchmarking a curriculum is to analyse its breadth and depth: in other words, the number and range of topics taught, and the amount of content within them. Students need a breadth of learning to understand a range of important topics and make connections between them. They also need to learn important topics in depth to extend their understanding.

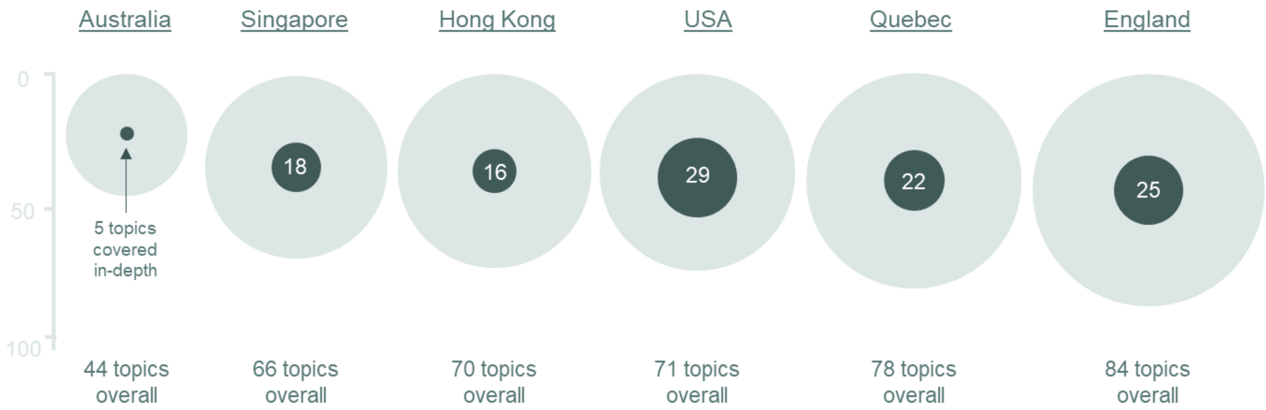
Curriculum experts often discuss breadth and depth of content in a curriculum as trade-offs; should more time be spent going deeper into certain topics or should more topics be covered but in less depth?[19] Sadly, the Australian science curriculum lacks both breadth and depth. It covers fewer topics and goes into depth in these topics far less often than other benchmarked curriculums. The Australian science curriculum is both narrow and shallow, with damaging consequences for learning and equity.

To calculate topic depth, each topic was ranked (highest to lowest) on their depth of content, calculated as the number of content items in each topic. The top quarter of topics (across all curriculums) was categorised as in depth. This means topic depth is a measure of the content in each topic; it is not a measure of how many words or dot points are written in the curriculum documents but the actual content that is to be taught for each topic (see Annex A for more information).

Our analysis shows that the Australian Curriculum covers only 44 science topics in the first nine years of school compared with an average of 74 topics in the other benchmarked systems. In other words, it enables Australian students to learn just under two-thirds of the number of topics, on average, that students in other benchmarked systems learn.

Figure 6 presents the total number of topics covered in the first nine years of each science curriculum – its breadth – and the number of topics it covers in depth.

Figure 6: Total number of topics and the number of topics covered in depth from Foundation to Year 8



Note: Topics are those in mandatory content from Foundation to Year 8. Content that is optional is not included in this data. Topic depth is based on a quartile analysis of the number of individual items of content in each topic. A topic was classified as being 'in depth' for a system if the number of content items within that topic was in the upper quartile. This figure compares cumulative coverage but does not compare the same number of years of instruction. Australia and the United States commence science in the Foundation Year. In England, Quebec and Hong Kong, science starts in Year 1. In Singapore, science starts in Year 3. England presents Years 7-9 content as a single stage, so this figure includes England's content up to Year 9. Alberta and Japan are not included in the above graph as only their primary school curriculum was included in the benchmarking.

[19] See, for example: Black 1995; William 2013; William H Schmidt et al. 1997.

Our analysis shows that the Australian Curriculum (F-8) covers just five topics in depth, compared with an average of 22 in other systems. These five topics are:

- Classification of living things (biological sciences): understanding how living things tend to be grouped based on shared characteristics, and understanding the differences between different types of living things.
- Ecosystems (biological sciences): understanding how living and non-living things interact within a specific environment, for example, how they depend on each other for survival.
- Particle model (chemical sciences): understanding the behaviour of matter using the movement and arrangement of particles, to describe and predict the behaviours and properties of solids, liquids and gases.
- Push and pull forces (physical sciences): understanding that a force is something that can cause movement, by one object pushing or pulling another object.
- The Earth, moon and sun (Earth and space sciences): understanding the relationship between the Earth, moon and sun, such as what a day and year are, why the sun appears to move across the sky, the phases of the moon, and the causes of tides.

It is interesting to consider topics covered in depth in the benchmarked curriculums that are not covered in depth in the Australian Curriculum, because it shows what content other systems are giving priority to. The following topics are all covered in depth in at least three benchmarked systems, but none of them are covered in depth in the mandatory content of the F-8 Australian Curriculum:

- Cells and organelles
- Contact and non-contact forces
- Electrical circuits
- Energy and food webs in ecosystems
- Energy conservation and transformation
- Gravity
- Heat energy
- Magnets and magnetism
- Mass, volume and density
- Materials
- Material properties
- Plant reproduction
- Reproductive system (animals)
- Spheres of the Earth
- Stars and the universe
- States of matter

The following two tables provide examples of topics that are taught in depth in benchmarked curriculums but not in Australia. Table 4 shows how the topic of magnets and magnetism is covered in depth in the curriculums of Alberta, England, and Singapore. Table 5 shows how the topic of cells and organelles is covered in depth in England, Hong Kong, Quebec, Singapore, and the United States.

Table 4: Content in the topic magnets and magnetism

<table>
<tr><td>Australia</td><td>Year 4
Identify how forces can be exerted by one object on another and investigate the effect of frictional, gravitational and magnetic forces on the motion of objects</td></tr>
<tr><td>Alberta</td><td>Year 4
Magnetic force is a non-contact force that attracts or repels magnetic materials.
Magnetic materials contain iron, cobalt, or nickel.
Magnetic force is strongest at the magnetic poles.
Magnets have two magnetic poles, known as north and south.
Opposite magnetic poles attract each other and like magnetic poles repel each other.
Both magnetic poles attract magnetic material.
Some materials can become magnetized by interacting with a magnet.</td></tr>
<tr><td>England</td><td>Year 3
Notice that some forces need contact between two objects, but magnetic forces can act at a distance.
Observe how magnets attract or repel each other and attract some materials and not others.
Compare and group together a variety of everyday materials on the basis of whether they are attracted to a magnet, and identify some magnetic materials.
Describe magnets as having two poles.
Predict whether two magnets will attract or repel each other, depending on which poles are facing.
Years 7-9
Magnetism
Magnetic poles, attraction and repulsion
Magnetic fields by plotting with compass, representation by field lines
Earth’s magnetism, compass and navigation
The magnetic effect of a current, electromagnets, D.C. motors (principles only).
Forces
Non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets and forces due to static electricity.</td></tr>
<tr><td>Singapore</td><td>Years 3-4
Recognise that a magnet can exert a push or a pull.
Identify the characteristics of magnets:
- magnets can be made of iron or steel
- magnets have two poles. A freely suspended bar magnet comes to rest pointing in a North-South direction
- unlike poles attract and like poles repel
- magnets attract magnetic materials
- Note: Recall of other magnetic materials such as nickel and cobalt is not required.
List some uses of magnets in everyday objects.
Years 7-8
show an understanding that a force can be a contact force (e.g., friction) or non-contact force, (e.g., magnetic force, gravitational force)</td></tr>
</table>

Table 5: Content in the topic cells and organelles

Australia	**Year 8** • Recognise cells as the basic units of living things, compare plant and animal cells, and describe the functions of specialised cell structures and organelles.
England	**Years 7-9** • Cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope. • The functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts. • The similarities and differences between plant and animal cells. • The role of diffusion in the movement of materials in and between cells.
Hong Kong	**Year 7** • Recognise cells as the basic unit of living things. • Distinguish between plant cells and animal cells. • Use a microscope to examine prepared slides of plant and animal tissues. • Identify the basic structures of cells, including cell wall (in plant cells), cell membrane, cytoplasm, nucleus, vacuole, chloroplasts (in plant cells). • State the functions of the basic structures of cells.
Quebec	**Years 7-8** • Defines the cell as the structural unit of life. • Names vital functions carried out by cells. • Distinguishes between animal and plant cells. • Identifies the main cellular components visible under a microscope (cell membrane, cytoplasm, nucleus, vacuoles). • Describes the role of the main cellular components visible under a microscope. • Distinguishes between osmosis and diffusion.

Singapore	**Years 5-6**
	• Show an understanding that a cell is a basic unit of life.
	• Identify the different parts of a typical plant cell and animal cell and relate the parts to the functions:
	  - parts of plant cell: cell wall, cell membrane, cytoplasm, nucleus and chloroplasts
	  - parts of animal cell: cell membrane, cytoplasm, nucleus
	
	Years 7-8
	• Show an understanding of the functions of the different parts of a typical cell, including the nucleus which contains genetic material (DNA) that can be passed down to the next generation.
	• Identify the different parts of a typical cell (plant or animal):
	  - cell wall
	  - cell membrane
	  - cytoplasm
	  - nucleus
	  - vacuole
	  - chloroplast
	• Show an understanding that typical plant and animal cells are models used to represent their various forms

United States	• Recognise that in multicellular organisms (e.g., plants and animals), cells are the basic building blocks that are organised into tissues, organs and systems • Infer whether an organism is an animal or a plant, based on its cell structures.
	Years 6-8 • All living things are made up of cells, which is the smallest unit that can be said to be alive. • An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). • Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. • *Clarification statement:* Emphasis is on the cell functioning as a whole system and the primary role of identified parts of the cell, specifically the nucleus, chloroplasts, mitochondria, cell membrane, and cell wall.

4 Poor sequencing and lack of specificity in the Australian Curriculum

High-quality curriculum enables students to learn and master content in a clear sequence that reflects the research on how students remember new information, building on what they have previously learnt.[20] All educators know that in science and other subjects sequencing is vital: students need to learn and understand simple concepts, such as the force of gravity, before they try and learn complex concepts such as how gravity causes planets to orbit the sun. Effective sequencing of content focuses on how it enables students to make better connections between related pieces of information, so that they can effectively build their understanding of topics over time.[21]

The Australian science curriculum contains multiple examples of poor and even non-existent sequencing, compared with clear sequencing in other systems. To illustrate the importance of good sequencing, let's consider how the content of animal body systems is included in Singapore's science curriculum. As Table 6 shows, this curriculum:

- re-visits content at each stage of learning, introducing specific body systems at students' earliest stage of learning, and then reintroducing this content at subsequent stages
- increases the complexity of information presented each time the topic is re-visited, so that students sequentially build expertise each time they are re-exposed to content
- is clear about what content to teach to ensure that student understanding grows with each stage of learning.

[20] Black 1995.
[21] While outside the scope of this paper, this draws on a number of areas of research including cognitive load research that highlights the importance of effectively sequencing new content. See for example: Australian Education Research Organisation 2023; Cowan 2008; Willingham 2007

Table 6: Singapore science curriculum: Content on animal body systems

	Singapore
Years 3-4	• Identify the organ systems and state their functions in humans (digestive, respiratory, circulatory, skeletal and muscular). • Identify the organs in the human digestive system (mouth, gullet, stomach, small intestine and large intestine) and describe their functions. *Note: This learning outcome introduces students to an overview of organ systems. Detailed knowledge of the muscular and skeletal systems (such as names of the bones/muscles in the body and descriptions of how they work) are not required.*
Years 5-6	• Identify the organs of the human respiratory and circulatory systems and describe their functions. • Recognise the integration of the different systems (digestive, respiratory and circulatory) in carrying out life processes. *Note: Detailed knowledge of respiratory system (e.g. alveoli) and circulatory system (e.g. heart chambers and valves) is not required.*
Years 7-8	• Recognise that in multicellular organisms (e.g., plants and animals), cells are the basic building blocks that are organised into tissues, organs and systems • Explain the importance of the digestive system • Explain how the main parts of the human digestive system work together to perform a function (e.g., mouth, gullet, stomach, small intestine, large intestine, rectum and anus) • Describe how a human digestive system helps in the digestion of food • Describe the functions of blood vessels in relation to the transport system in humans: ○ Arteries (carry blood away from the heart), ○ Veins (carry blood towards the heart) and ○ Capillaries (the site of exchange of substances) *Note: structures of the blood vessels and the heart are not required* • Recognise that the union of the nuclei of an egg and a sperm (inputs of a system) forms a fertilised egg which develops into a new individual (output of a system) • Recognise that the sexual reproductive system facilitates heredity (the passing down of genetic material from one generation to the next) • Describe briefly how the parts of the human male and female reproductive systems are involved in fertilisation • Describe how parts of the female reproductive system are involved in the menstrual cycle

Extending the above example, Table 7compares the sequencing of content on animal body systems in the Australian science curriculum and the science curriculum in England. Reflecting the clear sequencing of content in Singapore's curriculum, the science curriculum in England carefully details the sequencing of content required for effective teaching and learning.

The content in England starts with the fundamentals in the early years of primary school. Students are required to learn how to identify which parts of the body are associated with each sense, and the basic function of muscles and the skeleton. In Years 4-6, they are taught about the digestive and circulatory system in animals. This content provides a foundation for the content taught in Years 7-9, which goes into more depth about body systems with more detailed content on the digestive, respiratory, reproductive, skeletal and muscular systems.

Table 7: Sequence of animal body systems content in the science curriculums of England and Australia

<table>
<tr><th>England</th><th></th><th>Australia</th></tr>
<tr><td>Identify, name, draw and label the basic parts of the human body and say which part of the body is associated with each sense</td><td>Year 1</td><td></td></tr>
<tr><td></td><td>Year 2</td><td></td></tr>
<tr><td>Identify that humans and some other animals have skeletons and muscles for support, protection and movement</td><td>Year 3</td><td></td></tr>
<tr><td>Describe the simple functions of the basic parts of the digestive system in humans
Identify the different types of teeth in humans and their simple functions</td><td>Year 4</td><td></td></tr>
<tr><td></td><td>Year 5</td><td></td></tr>
<tr><td>Identify and name the main parts of the human circulatory system, and describe the functions of the heart, blood vessels and blood
Describe the ways in which nutrients and water are transported within animals, including humans</td><td>Year 6</td><td></td></tr>
<tr><td rowspan="3">The hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms
The structure and functions of the human skeleton, to include support, protection, movement and making blood cells
Biomechanics – the interaction between skeleton and muscles, including the measurement of force exerted by different muscles
The function of muscles and examples of antagonistic muscles
The tissues and organs of the human digestive system, including adaptations to function and how the digestive system digests food (enzymes simply as biological catalysts)
The importance of bacteria in the human digestive system
The structure and functions of the gas exchange system in humans, including adaptations to function
The mechanism of breathing to move air in and out of the lungs, using a pressure model to explain the movement of gases, including simple measurements of lung volume
Reproduction in humans (as an example of a mammal), including the structure and function of the male and female reproductive systems, menstrual cycle (without details of hormones), gametes, fertilisation, gestation and birth, to include the effect of maternal lifestyle on the foetus through the placenta</td><td>Year 7</td><td></td></tr>
<tr><td>Year 8</td><td>Analyse the relationship between structure and function of cells, tissues and organs in a plant and an animal organ system and explain how these systems enable survival of the individual</td></tr>
<tr><td>Year 9</td><td>Compare the role of body systems in regulating and coordinating the body's response to a stimulus, and describe the operation of a negative feedback mechanism
Describe the form and function of reproductive cells and organs in animals and plants, and analyse how the processes of sexual and asexual reproduction enable survival of the species</td></tr>
</table>

Note: While Foundation has not been included in the above figure, this year level does not include science content directly related to animal body systems. In health and physical education, there is a Foundation content description that refers to naming the body parts but it is in the context of making healthy and safe choices. The science curriculum in England presents early secondary content in a Years 7-9 block.

The contrast with the Australian Curriculum is stark. No body systems content is taught in Years F-7 of the Australian science curriculum. Only in Year 8 are students required to '*Analyse the relationship between structure and function of cells, tissues and organs in a plant and an animal organ system and explain how these systems enable survival of the individual*.' This is a large amount of content to learn without sequencing content in the preceding years to build important background understanding, as the science curriculums of England and Singapore do.

The above example highlights the difficulties of teaching the Australian Curriculum. Teachers in England can rely on a curriculum with clear and explicit sequencing of animal body systems content across the years of schooling. Students encounter new and increasingly complex content in a sequence that builds on prior learning. The Australian science curriculum, on the other hand, leaves teachers trying to teach complex content about animal body systems to students who have not had the benefit of sequenced content in previous years.

This highlights what is seemingly counter-intuitive: that adding more content to the Australian Curriculum would make it easier to teach. Simply adding more content on top of poorly sequenced material would create huge problems for Australian teachers.

Instead, a larger amount of carefully sequenced content, along with precision about what and what not to teach, can make teaching easier. It is impossible, for example, to look at the above example and not wonder how Australian teachers in Year 8 can possibly teach body systems content that curriculums in England and Singapore have spread across many years of primary and lower secondary school.

It is true that many Australian teachers add content, and provide learning tasks and activities, that enrich their students' learning experiences. But when a curriculum has as many holes in it as does the Australian Curriculum, a ceiling is inevitably placed on student learning. Individual teachers shouldn't be expected teach content such as the digestive system in Year 4 (when it is taught in Singapore and England) a full four years before it is included in the Australian Curriculum.

4.1 Lack of specificity in the Australian science curriculum

As well as falling short in sequencing, science content in the Australian Curriculum also lacks specificity. This makes it even harder for teachers to know what to teach and at what breadth and depth. As a result, Australian teachers are regularly required to make judgement calls on what content to teach – such as which body systems to cover and to what depth when teaching Year 8 biological sciences, as illustrated above.

To provide another example of where the Australian Curriculum lacks specificity, consider the content description on the topic of cells and organelles, also at Year 8: '*recognise cells as the basic units of living things, compare plant and animal cells, and describe the functions of specialised cell structures and organelles*'. England, Hong Kong, Quebec, Singapore and the United States all specify which organelles must be taught to students (see Table 5 in the previous chapter on breadth and depth). The Australian Curriculum provides this information only in optional elaborations. In marked contrast to five other benchmarked curriculums, it contains no requirement about which organelles to cover.

The lack of specificity in the curriculum's science content descriptions isn't confined to Year 8 biological sciences. For example, in Year 3 chemical sciences the Australian Curriculum states that students should '*investigate the observable properties of solids and liquids and how adding or removing heat energy leads to a change of state*'. The statement is so broad it inevitably raises questions for teachers seeking clarity on what to teach. They might reasonably wonder: Do I first need to teach what matter is? Which observable properties do I teach? How do I introduce change of state without talking about gases?

By contrast, consider Alberta's Year 3 curriculum. It clearly states the content to be taught about the properties of solids, liquids and gases, and how states of matter can change by adding or removing heat. The differences between the two curriculums are illustrated in Table 8.

Table 8: Year 3 chemical sciences content descriptions in Australia and Alberta

Australia	• Investigate the observable properties of solids and liquids and how adding or removing heat energy leads to a change of state
Alberta	• Matter is anything that takes up space and has weight • States of matter include solid, liquid, and gas • Melting is a change of state from solid to liquid • Freezing is a change of state from liquid to solid • Evaporation is a change of state from liquid to gas • Condensation is a change of state from gas to liquid • A solid is a state of matter that has a definite shape and volume • A liquid is a state of matter that has a definite volume but no definite shape • A liquid flows and takes the shape of the container it is in • A gas is a state of matter that has neither definite shape nor definite volume • A gas flows easily and expands to the size of the container it is in • Volume is the amount of space a solid, liquid, or gas takes up • Substances are made of matter that has not been mixed with other matter, including water • The temperature at which a substance changes from solid to liquid is called the melting point • The temperature at which a substance changes from liquid to solid is called the freezing point • The melting and freezing points of a substance are the same temperature • The temperature at which a substance changes from liquid to gas is called the boiling point • The melting/freezing point of water is 0ºC • The boiling point of water is 100ºC

Without clear direction on content, teachers have no way to guarantee that all students build shared knowledge and skills that prepares them equally for their senior years of schooling and beyond. Linking back to the body systems example above, one teacher's class may receive multiple lessons that go deep into content on the digestive system. Another class ten kilometres away may receive introductory content on each major body system without covering any in depth. Yet both learning experiences are aligned with the Australian Curriculum, despite the huge variation in learning between them. This reality is a far reach from ACARA's vision that a curriculum achieves equity by providing '*a clear, shared understanding of what young people should be taught and the quality of learning expected of them, regardless of their circumstances, the type of school that they attend or the location of their school*'.[22]

[22] Australian Curriculum Assessment and Reporting Authority 2020.

5 Problems with optional content

The content detailed in a curriculum provides the curriculum entitlement: what each student has a right to learn. The lack of content in the Australian Curriculum means that students have a reduced curriculum entitlement: the right to learn about half the science content, on average, over the first nine years of school as students in the other systems benchmarked.

The Australian Curriculum is an outlier in making a substantial proportion of content optional. This erodes the curriculum entitlement of Australian students: making some content optional means we are fine with some students not being taught it. This is why high-quality curriculums usually make only small amounts of content optional.

For example, 2 per cent of content in the Hong Kong lower secondary science curriculum is described as optional learning activities. Hong Kong and Singapore also both include optional extension content. Extension content is intended to extend or challenge students beyond the regular content expected at each stage of learning, and therefore it does not reduce the amount of content that every student is guaranteed to have the opportunity to learn.

By contrast, our analysis shows that just under 40 per cent of content in the Australian science curriculum from Foundation to Year 10 is optional to be taught to students. Such content is defined by the term, 'optional elaborations', which ACARA defines as '…*suggestions of ways to teach the content description and connect it to general capabilities and cross-curriculum priorities. Content elaborations are optional*.'[23]

To illustrate, Table 9 shows the Year 2 Earth and space sciences content description and optional elaborations. The content description requires that students learn that Earth is a planet in the solar system and that the sun, moon, planets and stars can change position in the sky. The elaborations make it optional for students to learn about how shadow length changes with the changing position of the sun; that the appearance of the moon changes at different times of the month and year; and that some events in the sky follow regular and irregular patterns.

[23] Australian Curriculum, Assessment and Reporting Authority n.d.

Table 9: Example of optional elaborations in the Australian Curriculum

Year 2 – Earth and space sciences	
Year 2	**Content description:** recognise Earth is a planet in the solar system and identify patterns in the changing position of the sun, moon, planets and stars in the sky **Optional elaborations:** • *Identifying celestial objects that can be observed in space such as the sun, moon, stars and planets* • *Viewing images or video of Earth from space, describing the shape of Earth and discussing how the images or video were taken* • *Exploring representations of the solar system and identifying Earth and other planets* • *Observing that some phenomena in the sky are only visible during the day and others during the night* • *Investigating how shadow length changes with the changing position of the sun, identifying patterns and making predictions* • *Creating a class moon diary across a month, identifying patterns in the changing shape of the moon and making predictions* • *Observing and describing short-term and longer-term patterns of events that occur in the sky, such as the appearance of the moon and stars at different times of the month or year* • *Distinguishing between regular events that occur in the sky, such as the appearance of a full moon, and irregular events such as 'blue', 'blood' or 'super' moons* • *Exploring how cultural stories of First Nations Peoples of Australia describe the patterns in the changing positions of the sun, moon and stars*

Unfortunately, rather than simply being elaborations of mandatory content or suggestions of ways to teach that content, optional elaborations in the Australian Curriculum often include large amounts of *new* content – sometimes even new topics.

For example, the Australian Curriculum introduces the following topics as optional elaborations when in most of the systems we benchmarked, they are mandatory:

- Concentrations and solutions in chemical sciences
- Simple machines in physical sciences
- Weather in Earth and space sciences
- Conservation in Earth and space sciences
- Human management of natural resources in Earth and space sciences.

By contrast, optional content in the science curriculum of England – defined as 'notes and guidance' – provides useful advice for teachers for how to teach the curriculum's mandatory content. An example of optional content in England's Year 6 science curriculum, set out in Table 10 below, suggests that when learning about evolution and inheritance, students could also learn about how the insulating fur of the arctic fox enables them to survive. The notes and guidance also highlight that the topic of evolution builds on what students learned about fossils in Year 3.

Table 10: Example of optional content in England

Year 6 - Evolution and inheritance
Statutory requirements • recognise that living things have changed over time and that fossils provide information about living things that inhabited the Earth millions of years ago • recognise that living things produce offspring of the same kind, but normally offspring vary and are not identical to their parents • identify how animals and plants are adapted to suit their environment in different ways and that adaptation may lead to evolution.
Notes and guidance (non-statutory) Building on what they learned about fossils in the topic on rocks in year 3, pupils should find out more about how living things on Earth have changed over time. They should be introduced to the idea that characteristics are passed from parents to their offspring, for instance by considering different breeds of dogs, and what happens when, for example, labradors are crossed with poodles. They should also appreciate that variation in offspring over time can make animals more or less able to survive in particular environments, for example, by exploring how giraffes' necks got longer, or the development of insulating fur on the arctic fox. Pupils might find out about the work of palaeontologists such as Mary Anning and about how Charles Darwin and Alfred Wallace developed their ideas on evolution. **Note:** At this stage, pupils are not expected to understand how genes and chromosomes work.

This example from England illustrates clearly how optional content could work in a curriculum. It makes connections to prior learning, and it sets out specific examples of extra content students could learn. It does not introduce any new topics.

Would treating optional content as mandatory change the benchmarking results?

It might be tempting to argue that if we include all optional content then the amount of content in the Australian Curriculum would be similar to that of other systems. But that is not the case. Even if teachers taught all the optional content, and interpreted this content in the same way, the Australian science curriculum would still have about 30 per cent less content than the average of other science curriculums benchmarked.

Moreover, it would be wrong to have any confidence that content clearly marked as optional in the Australian Curriculum is actually taught in schools. Unfortunately, we know very little about what mandatory content, let alone what optional content, is and is not covered in Australian schools and classrooms. All we know is that levels of curriculum planning and implementation vary greatly.[24] Its optional content is just another way the Australian science curriculum is an outlier in international benchmarking.

[24] Hunter et al. 2022

6 How to solve the problems with the Australian Curriculum

We can no longer ignore the problems with the Australian Curriculum. Change must occur but simply repeating the same process that created the problems in the first place will not achieve it. We need to recognise that the process through which the Australian Curriculum is developed is broken. The Australian science curriculum is not based on:

- Leading research highlighting the importance to equity and student learning of a content-rich curriculum, research that has clearly been a focus of the high-performing and comparable systems benchmarked in this report.[25]
- Comprehensive quality benchmarking of curriculum content against high-performing and comparable systems overseas. The Australian science curriculum would never have been permitted to have just half the content, on average, of comparable systems over the first nine years of schooling if such benchmarking had been undertaken during development of the curriculum.
- Curriculum mapping that analyses sequencing of content; there would not be the sequencing problems in the Australian science curriculum if quality curriculum mapping had been completed.

The process of curriculum development in Australia is too focused on collating and analysing stakeholder feedback. Stakeholders need to speak and be heard but their feedback should be one component of curriculum development and review.

The Australian Curriculum review and development process is also too influenced by a general education debate that is full of high-level discussion and broad objectives but very light on the detail of the curriculum. Yet it is the detail that is taught and assessed in schools and classrooms; the detail that students learn. The detail of the curriculum is what matters.

[25] For example, the creators of the Next Generation Science Standards (NGSS), the US science curriculum benchmarked in this report, was benchmarked 'against countries whose students perform well in science and engineering fields, including Finland, South Korea, China, Canada, England, Hungary, Ireland, Japan, and Singapore'. See Next Generation Science Standards n.d.

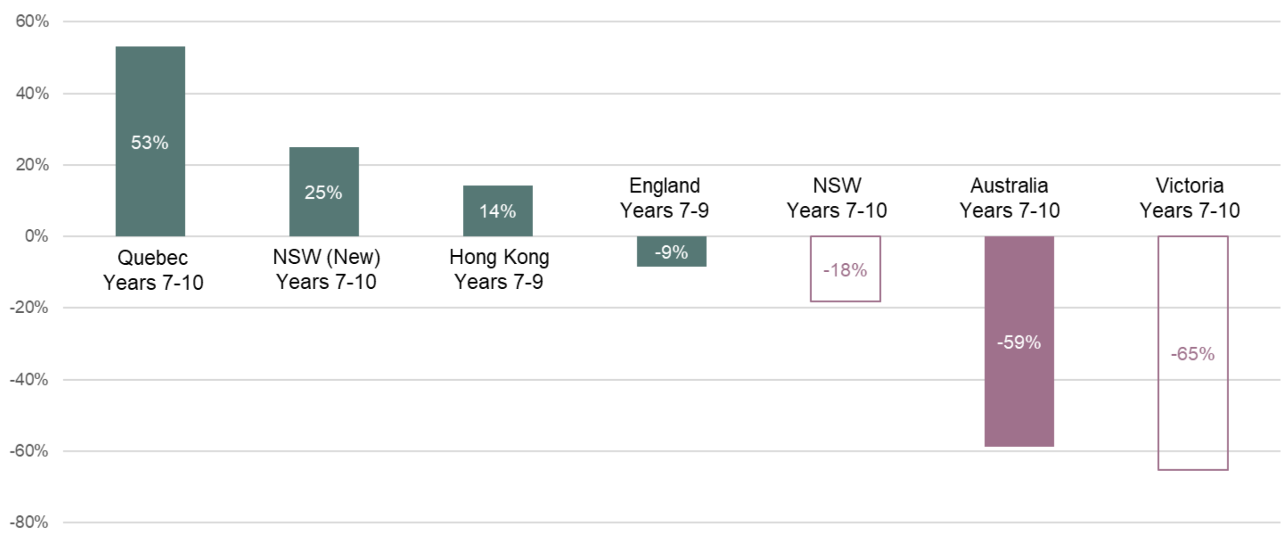
Hope for the future: recent curriculum reform in New South Wales

While a complete overhaul of the Australian Curriculum seems like an impossible task, hope lies in the example set by the development of the new NSW curriculum. Australian states and territories are required to implement the Australian Curriculum. New South Wales and Victoria each have their own curriculum (called syllabus in New South Wales) that is adapted from the Australian Curriculum. New South Wales has released a draft of its new science curriculum for Years 7-10. Victoria, whose existing curriculum is based on Version 8.4 of the Australian Curriculum, plans to release its new science curriculum in 2024.[26]

Learning First also benchmarked the existing and new versions of the NSW science curriculum (Years 7-10) and the existing version of the Victorian curriculum (Years 7-10) against some other systems examined in this report. Figure 7 presents the percentage of content included in these systems' Years 7-10 science curriculums. Victoria has slightly less content than the Australian Curriculum. But the big story is the increase in the amount of science content in the NSW curriculum.

The new NSW science curriculum has just over 50 per cent more content than the old one. It has less science content than Quebec but more than Hong Kong and England. However, England and Hong Kong have only been benchmarked for Years 7-9. A simple calculation of amount of content per year means that the NSW secondary school science curriculum has about the same amount of content per year as the secondary school science curriculum in England, and a bit less content per year as that in Hong Kong. All the research indicates that these changes will have a significant positive impact on student learning and equity in New South Wales school education.

Figure 7: Percentage of content included in systems' curriculums compared to the average, from Year 7-10



The process undertaken in New South Wales was not perfect; more work is always needed. But it was led by curriculum leaders who worked from the research on what makes a quality curriculum, and who analysed and benchmarked the content of curriculums from around the world.[27] Their work shows that an effective overhaul of the Australian Curriculum is possible.

[26] Victorian Curriculum and Assessment Authority Bulletin: Accessed at https://www.vcaa.vic.edu.au/news-and-events/bulletins-and-updates/bulletin/2023/93November/Pages/93NovemberF-10.aspx.
[27] Disclosure: Learning First was an advisor to NESA on the development of its new curriculum.

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8 Annex A: Methodology: How did we undertake science curriculum benchmarking?

A curriculum is the foundation of an education system, providing the guaranteed learning entitlement for all students. To quote the Australian Curriculum, Assessment and Reporting Authority (ACARA), the body responsible for developing the Australian Curriculum:

'*The Australian Curriculum describes to teachers, parents, students and others in the wider community what is to be taught and the quality of learning expected of young people as they progress through school*.'

This report presents the findings of a benchmarking analysis Learning First conducted to compare the documented content of the Australian science curriculum with the documented content of other systems' science curriculums. The documented curriculum can be thought of as the guaranteed learning entitlement for all students, regardless of background.

What is content benchmarking?

Unsurprisingly, curriculums of different systems around the world look different. They are often structured in different ways and state the content to be taught in different ways.

For example, the Australian science curriculum consists of three strands (Science understanding, Science as a human endeavour and Science inquiry) and includes:

- **Achievement standards** for each learning area or subject that describe the learning expected of students at each year level or band of years.
- **Content descriptions** that describe what is to be taught and what students are expected to learn.
- **Optional content elaborations** that give teachers ideas about how they might teach the content.

In contrast, the Hong Kong science curriculum for Years 7-9 is divided into thematic units, and the content is presented in three categories:

- Students should learn
- Students should be able to
- Suggested learning and teaching activities.

Curriculum content benchmarking involves analysing content that is presented in different ways in different curriculums. Content benchmarking does not focus on which structure is best, or the best way to write content. Instead, content benchmarking is focused on identifying the content in a curriculum at the most granular level, irrespective of how that content is written or presented.

Learning First analysed the content in each curriculum in order to identify the individual pieces of scientific knowledge within each curriculum document. Each piece of scientific knowledge was coded as an individual content 'item'. One item of content represents one piece of scientific knowledge – for example, 'the cell is the basic unit of life' – that students are expected to learn. Every content item was identified as either mandatory or optional to teach.

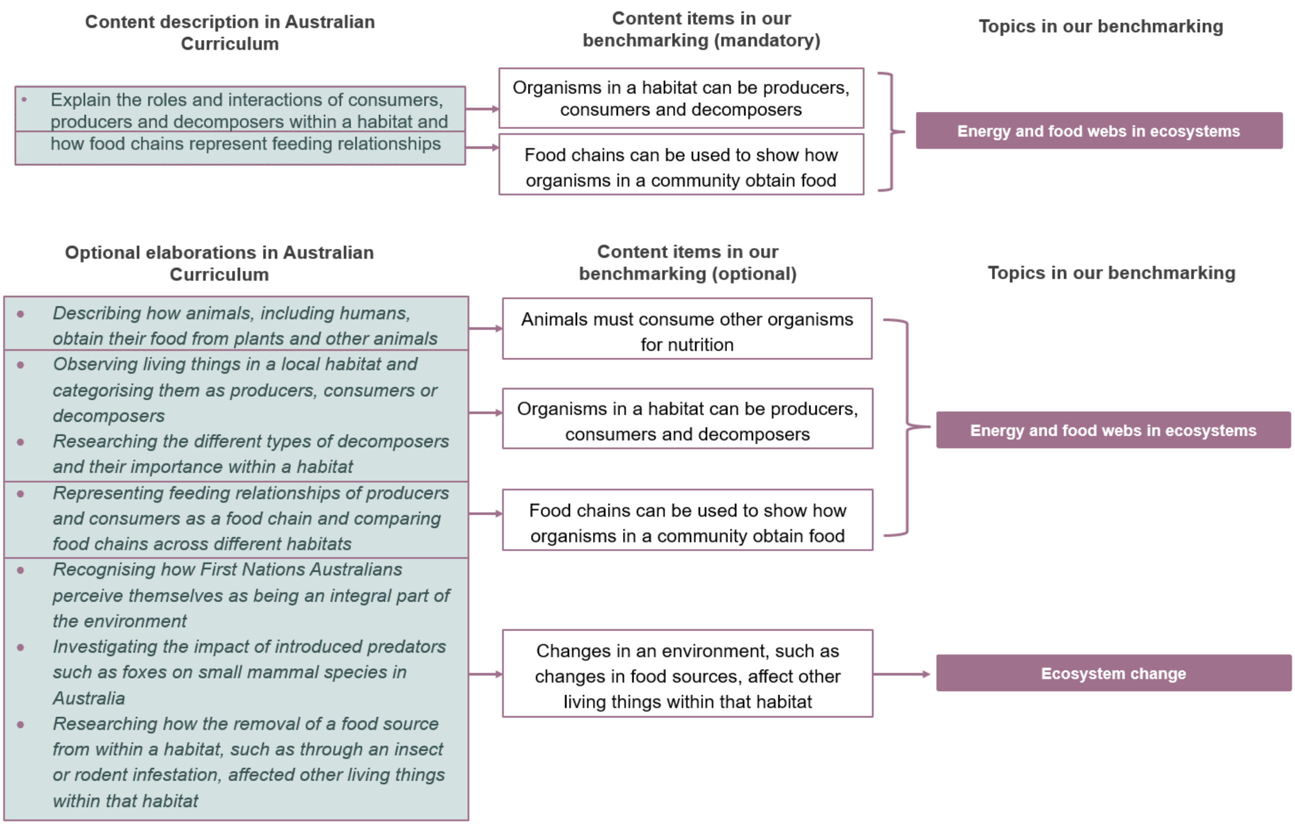
It is possible for curriculums to have a high word count and contain few items of content, and, conversely, to have a low word count and contain several items of content. Benchmarking distilled text in curriculum documents to their composite items of content, irrespective of the structure or wording of the statement. This was important to make fair comparisons between each systems' curriculum.

Learning First did not start with a universal list of content items and then check which curriculums did or did not include them. Rather, if a discrete piece of scientific knowledge was identified in any of the curriculums analysed for this report, it was coded as a content item, and cross-referenced against every other curriculum to determine whether it existed in other systems' science content.

After a database of content items was developed for all systems included in the analysis, content items were then sorted into topics. A topic is a disciplinary area of knowledge made up of closely related content items.

To illustrate the coding process, let's consider the Australian Curriculum's Year 4 biological sciences content description '*explain the roles and interactions of consumers, producers and decomposers within a habitat and how food chains represent feeding relationships*'. Our benchmarking shows that this content description forms two unique content items, contributing to one topic (Energy and food webs in ecosystems) within our benchmarking database. In addition, the optional elaborations have been coded as four optional content items (two of which were not present in the content description), contributing to an additional topic (Ecosystem change). Figure 8 shows this coding.

Figure 8: Illustration of our benchmarking process



As shown above, a single dot point can contribute to more than one content item. For example, the content description '*explain the roles and interactions of consumers, producers and decomposers within a habitat and how food chains represent feeding relationships'* above contributes to two content items. In some cases, multiple dot points can contribute to only one content item. For example, the optional elaborations '*observing living things in a local environment and categorising them as producers, consumers and decomposers*' and '*researching different types of decomposers and their importance within a habitat*' both contribute to one content item. How we have handled duplicate content items is described further below.

Each topic was then sorted into a domain, using the sub-strands within the Science understanding strand of the Australian Curriculum. These four sub-strands, and hence the four domains used for this benchmarking, are biological sciences, Earth and space sciences, physical sciences and chemical sciences[28].

What content was coded for the Australian Curriculum?

ACARA describes the Australian science curriculum as year levels from Foundation to Year 10.[29] Content is organised under three interrelated strands:

- Science understanding
- Science as a human endeavour
- Science inquiry

A description of each strand is included at the bottom of this box.

The benchmarking analysis coded the scientific knowledge within the content descriptions and optional content elaborations for each of the three strands. The Science understanding strand was coded first, and the vast majority of content items for the Australian science curriculum were identified within this strand. Science as a human endeavour and Science inquiry were then reviewed and any additional scientific knowledge within these strands added to the database – noting that in most instances, the knowledge identified within these strands had already been identified and coded as content items through the review of the Science understanding strand.

It should be noted that science skills identified within the Science inquiry strand cannot be benchmarked in the same manner as science content. This is in part because curriculums don't quantify how often science skills should be applied in teaching a domain or topic.

Australian science curriculum strands: further detail as described by ACARA

In the **Science understanding** strand, students learn to select and integrate appropriate science knowledge to explain and predict phenomena and apply that knowledge to new situations. Science knowledge refers to facts, concepts, principles, laws, theories and models that have been established over time.

In the **Science as a human endeavour** strand, students learn about the nature of science, including the role of science inquiry in developing science knowledge, and the factors that affect the use and advancement of science. Students learn that through science, humans seek to improve their understanding of and explanations for the natural and physical world, and that science knowledge is refined and revised as new evidence becomes available. They appreciate that science influences society by posing and responding to ethical, environmental and social questions, and individual and collective scientific research is itself influenced by the needs and priorities of society. This strand highlights the development of science as a unique way of knowing and doing, and the role of science in contemporary decision-making and problem-solving.

In the **Science inquiry** strand, students learn about investigating ideas, developing explanations, solving problems, drawing valid conclusions, evaluating claims and constructing evidence-based arguments. Students learn the essential practices of science, including identifying and posing questions; planning, conducting and reflecting on investigations; processing, analysing and interpreting evidence; and communicating findings. Science investigations are activities in which ideas, predictions or hypotheses are tested and conclusions are drawn in response to a question or problem. They can involve a range of activities including experimental testing, field work, locating and using information sources, conducting surveys, and using modelling and simulations. The choice of the approach taken will depend on the context and aims of the investigation.

[28] These domains are referred to differently across systems. For example, biological sciences is sometimes referred to as life sciences.
[29] ACARA 2023.

Some systems, such as Hong Kong and Singapore, include optional *extension* content within their curriculums. Optional extension content was not coded as part of this benchmarking analysis as our focus was on general science pathways. All other optional content within a curriculum was coded.

Confirming the content items, topics and domains for each systems' curriculums involved multiple rounds of validation of the database by curriculum experts, data analysts and current and former science teachers who collectively have studied each domain at a tertiary level.

The total number of topics and items of content under each domain across all curriculums were:

	Biological sciences	Chemical sciences	Physical sciences	Earth and space sciences
Topics	35	28	29	27
Items of content	362	243	349	253

To illustrate, the chemical sciences domain comprised 28 topics:

- Acids and bases
- Atomic theory
- Chemical bonding
- Chemical change
- Chemical formulas and equations
- Chemical reactions
- Combustion
- Concentration and solutions
- Displacement reactions
- Electrochemistry
- Electronic structure and valency
- Elements and compounds
- Hydrocarbons
- Mass, volume and density
- Materials
- Material properties
- Metals
- Neutralisation reactions
- Particle model
- Periodic table of elements
- Physical change
- Pure and impure substances
- Radioactive decay and fusion
- Rate of reaction
- Solubility
- States of matter
- Synthesis and decomposition reactions
- Thermal expansion

Among these topics, the particle model topic contained 12 items of content:

- All matter is made of tiny particles
- Attractive forces are strongest in solids
- Attractive forces are weakest in gases
- Gas particles move randomly (Brownian motion)
- Particles in gases are separated by large spaces
- Particles in liquids are able to slide over each-other
- Particles in solids are close together and vibrate
- Particles of matter are in constant motion
- The speed and distance between particles increases with temperature
- The speed of particles changes with heat and explains changes of state
- There are attractive forces between particles
- There is empty space between particles.

Once we had established and validated the database to represent the benchmarked curriculums as individual items of content sorted into topics and domains, we could then make comparisons between systems.

Which systems were included in the benchmarking?

The systems and associated science curriculums included in the benchmarking analysis were:

System	Curriculum
Australia	Australian Curriculum: Science (Version 9.0), Foundation to Year 10
New South Wales	New South Wales Draft Syllabus: Science (2022), Year 7 to Year 10
Victoria	Victorian Curriculum: Science, Foundation to Year 10
Alberta (Canada)	Alberta Curriculum: Science (2022-2023 pilot), Kindergarten to Year 6
England	National Curriculum in England: Science (2013), Year 1 to Year 9
Hong Kong	Hong Kong Curriculum: Science (2017), Year 1 to Year 9
Japan	Japan Curriculum: Science (2017), Year 3 to Year 6
Quebec (Canada)	Quebec Education Program: Science and Technology (2009), Year 1 to Year 6 Quebec Education Program: Science and Technology (2011), Year 7 to Year 10[30]
Singapore	Singapore Syllabus: Science (2013), Year 3 to Year 6 Singapore Syllabus: Science (2020), Year 7 to Year 8
The United States	Next Generation Science Standards (2017), Kindergarten to Year 8

When selecting systems to include in the benchmarking analysis, we prioritised focusing on systems that have shown high performance in large-scale international assessments of student achievement in science[31] or are often commented on in public discourse as a comparator to Australia. In addition, for a system to be included in the analysis their curriculum needed to be publicly accessible and in English.

New South Wales and Victoria were included because they adapt the Australian Curriculum to create state-specific versions. All other states and territories in Australia use the Australian Curriculum for science.

If a system (for example, Quebec) included technology content within its science curriculum that did not relate to the four domains – biological sciences, Earth and space sciences, physical sciences and chemical sciences – this content was not coded and hence was not included in the content item database.

An English translation of Japan's curriculum could only be accessed from Years 3-6, hence only these years were benchmarked.

[30] General Education Path for Cycle 2

[31] For example, the Organisation for Economic Co-operation and Development's (OECD) Programme for International Student Assessment (PISA), International Association for the Evaluation of Educational Achievement's (IEA) Trends in International Mathematics and Science Study (TIMSS).

While Alberta's and Japan's science curriculums have been included in this analysis, only primary school curriculum content was available to benchmark. This means data from these systems has not been included in graphs comparing the F-8 curriculums of systems in the report.

The benchmarked curriculums have their levels shown as 'years' to align with how the Australian Curriculum represents the different stages of instruction. However, not all curriculums formally use this language to represent each level. For example, what the Australian Curriculum calls Year 1, the United States calls First Grade.

The science curriculums of New South Wales, Victoria, England (for secondary), Hong Kong (for primary), Quebec, Singapore and the United States represent their levels of instruction as multi-year stages (for example, Years 7-9 in England is called Key Stage 3). When a curriculum has multi-year levels of instruction, content within that multi-year stage, such as science content in Key Stage 3 for England, was assigned to the earliest year level of that stage.

All curriculum content that spanned a multi-year stage still had clear cut-offs with Australia's delineation between primary (up to Year 6) and secondary (from Year 7) school. The only exception was the United States, which groups content in Years 6-8 under the framework of middle school. In this instance, middle school content was coded to Year 7 within our database, and represented with secondary rather than primary data when a distinction between these two stages of schooling is made in the report.

It was not possible to compare the exact same number of levels of instruction across each system. Students in Australia, Alberta and the United States are taught science from Foundation year. In England, Hong Kong and Quebec, science starts in Year 1. In Japan and Singapore, science starts in Year 3.

Where possible, curriculums were benchmarked up to Year 10. For some systems, this was not possible because the curriculum was not available past a certain year level, or because the science curriculum becomes specialised beyond Years 8-9 (one example is specialist chemistry subjects). This is why most comparisons in this report are from Foundation to Year 8. However, England presents Years 7-9 content as a single stage, meaning England's content was coded up to Year 9, rather than Year 8.

How are the results of the benchmarking analysis represented?

To quantify the volume of content covered in each curriculum it was important to ensure that duplicate content items were removed. Each curriculum includes duplicate content items at different year levels. This was anticipated, as you would logically expect there to be some overlap in content items at different year levels when a topic is revisited at increasing levels of complexity in year level increments. To fairly compare the number of individual content items between systems, duplicates of content items were not included in any of the data, graphs, tables or figures in this report.

The data, graphs, tables and figures in this report represent the output of this benchmarking in two ways: as the number of content items in various systems' science curriculums as a percentage comparison to the average (mean); and as the number of topics in total and number of topics in depth. Topic depth is based on a quartile analysis of the number of individual items of content in each topic. A topic was classified as being 'in depth' for a system if the number of content items within that topic was in the upper quartile (for all topics and systems).

To complement the quantifiable output of the benchmarking, the report also includes several examples of the differences between content in different curriculums, shown as excerpts drawn directly from curriculums.

What about science content in non-science subjects?

When designing curriculums, systems must decide where to put content that might fit into several learning areas. For example, content on body systems may be part of science, health, or both; and content on plate tectonics may be part of science, geography, or both. Accordingly, to ensure that our benchmarking analysis did not produce misleading results about the amount of science content within the *overall* Australian Curriculum, we also analysed the curriculum documents of other subjects for each system. The purpose of doing so was to check if science-related content appeared in subjects other than science.

It was important to determine whether the Australian science curriculum compensated for its lack of content by including science content in other subjects, such as health and physical education and geography. This analysis showed that most systems include some science content in these subjects, and that the Australian Curriculum does not include more science content in health and physical education and geography than other systems.

The example below compares content on body systems in the health and physical education curriculums and content on plate tectonics in the geography curriculums of Australia with two other systems.[32]

Health and physical education

The Australian Curriculum health and physical education content descriptions do not include body systems content in any year level from Foundation to Year 10. There is a Foundation content description that refers to naming the body parts, but it is in the context of making healthy and safe choices (*'demonstrate protective behaviours, name body parts and rehearse help-seeking strategies that help keep them [students] safe'*). In contrast, Quebec's health and physical education curriculum includes substantial content about body systems.

In Years 3 to 6 of health and physical education, primary school students in Quebec are expected to understand how key body systems relate to physical activity. They should be able to explain '*the main function of the cardiovascular system during physical activity*', '*the main function of the respiratory system during physical activity*', and '*the overall function of the muscular system during physical activity*'. In Years 5 and 6 they also learn about elements of cardiovascular endurance and muscular strength and endurance.

In secondary school, Quebec students are expected to continue to learn science content in health and physical education. Building on the content of the primary health and physical education curriculum, secondary students are expected to learn more detailed content about body systems. For example, by Year 10 a student should be able to:

- Name the main components of the cardiovascular, respiratory and muscular systems involved in carrying out physical activities: for example, heart, lungs and abdominal muscles
- In simple terms or using a diagram, explain the main systems involved in physical activity: for example, 'The cardiovascular system carries oxygen and nutrients to the muscles in accordance with the physical effort involved'.

Geography

The Australian Curriculum includes some optional content about plate tectonics and rock formation in Year 8 geography. England's geography curriculum includes information on the key process of physical

[32] None of the content referenced from the health and physical education or geography curriculums has been coded for inclusion in the science benchmarking database.

geography relating to plate tectonics in Years 7-9, whereas Quebec includes limited content about plate tectonics or rock formation in its geography curriculum at primary or secondary. The Australian Curriculum therefore includes a little more optional science content about plate tectonics than Quebec in its geography curriculum but less than England.

The Australian Curriculum content for Year 8 geography includes two content descriptions that may be taught in ways that relate to scientific content about plate tectonics, however it is possible for students to address the content descriptions without a scientific focus. The content descriptions are that students learn about '*geomorphological processes that produce different landscapes and significant landforms*' and '*the causes and impacts of a geomorphological hazard on people, places and environments, and the effects of responses*'. Geomorphological processes are the physical, chemical and biological processes that create certain geographic features. In this regard, plate tectonics may be taught as part of these content descriptions.

The optional elaborations do provide some suggestions for what might be included, such as '*explaining how tectonics, volcanism, folding, faulting, chemical weathering and physical weathering such as erosion, transportation and deposition shape places; for example, folding – MacDonnell Ranges, Northern Territory, Australia; faulting – Great Sumatran Fault (Semangko Fault), Indonesia; volcanism – Krakatoa, Indonesia'*. It is important to note, however, that processes such as the movement of tectonic plates are not required to be taught within these optional content descriptions. Similarly, there is an optional elaboration that suggests '*identifying the causes of a geomorphological hazard such as a volcanic eruption, earthquake, tsunami, landslide or avalanche*.' Understanding the causes of folding, faulting, volcanic eruptions, earthquakes or tsunamis is likely to require an understanding of plate tectonics; however, both elaborations given in this example are optional, and other types of geomorphological processes or hazards could be taught that don't relate to plate tectonics, such as weathering. Therefore, while it is reasonable to assume that students in Year 8 geography will develop an understanding of at least one area of either plate tectonics, rock formation or erosion and weathering, there is no guarantee that students will learn about plate tectonics.

For the avoidance of doubt, Learning First is not suggesting that there should be more science content in subjects like health and physical education and geography. Nor are we suggesting that there is a 'right' or 'wrong' place to include content that could reasonably fit into more than one subject. Rather, the above examples indicate that the Australian Curriculum for health and physical education and geography include limited scientific content, whereas some other systems benchmarked do include further scientific content within these subjects.