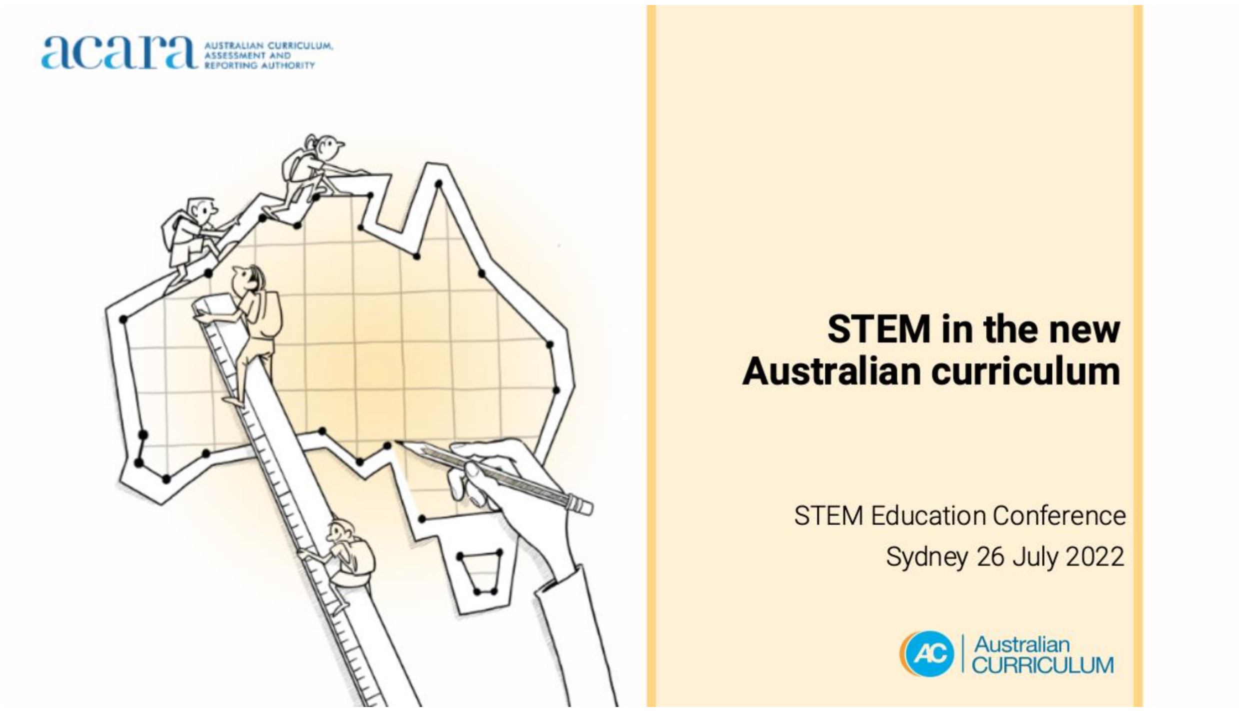
The Role of STEM in the new Australian curriculum

STEM Education Conference, Sydney
26 July 2022



Lovely to be here and thank you for having me.

Before we commence, I wish to acknowledge that we are meeting today on the traditional lands of the Gadigal people of the Eora nation and I pay our respects to their Elders for they have been, are, and will continue to be true educators, holding and passing on, from generation to generations over tens of thousands of years, the memories, the traditions, the culture and hopes of Aboriginal and Torres Strait Islander Australia, and by extension, to all of us. I extend that respect to Aboriginal and Torres Strait Islander peoples here today.

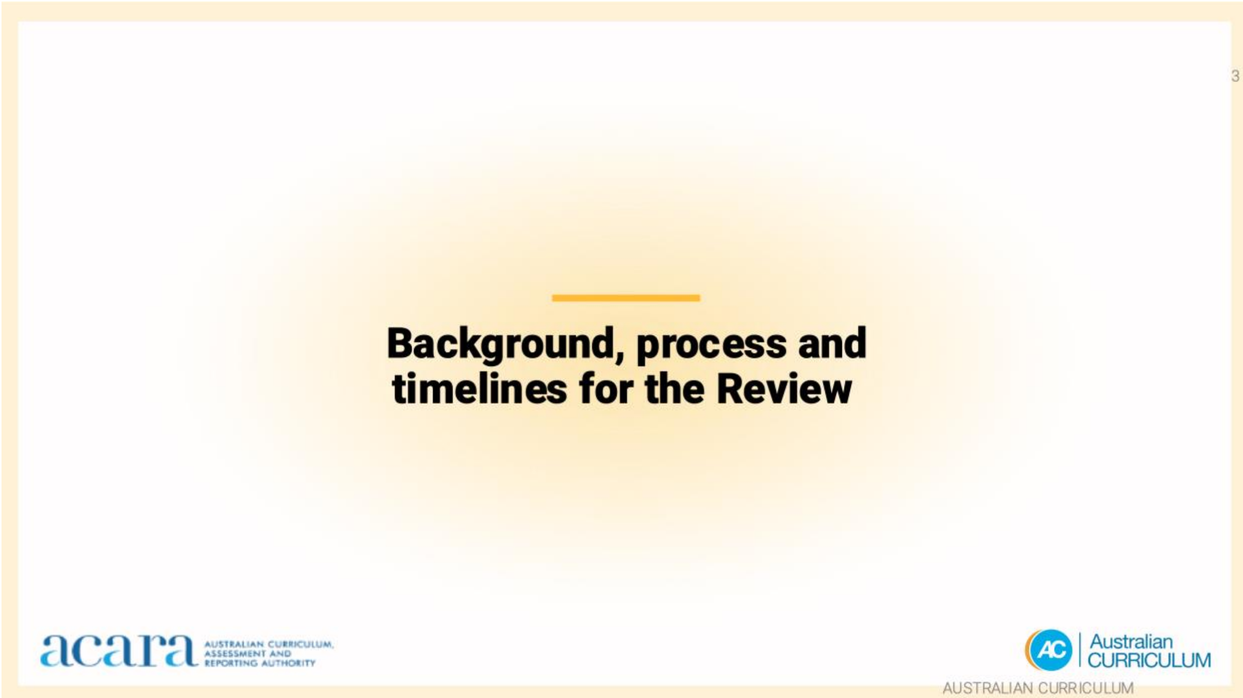
I'd also like to acknowledge all the hard-working teachers and school leaders in the room. I regard you as, in some sense, elders for the broader Australian community because you have entrusted with passing on knowledge that is transformational both for individual students and for society more broadly.

In April this year, all Education Ministers approved the new Australian Curriculum, version 9.0, after the first comprehensive review since 2014.

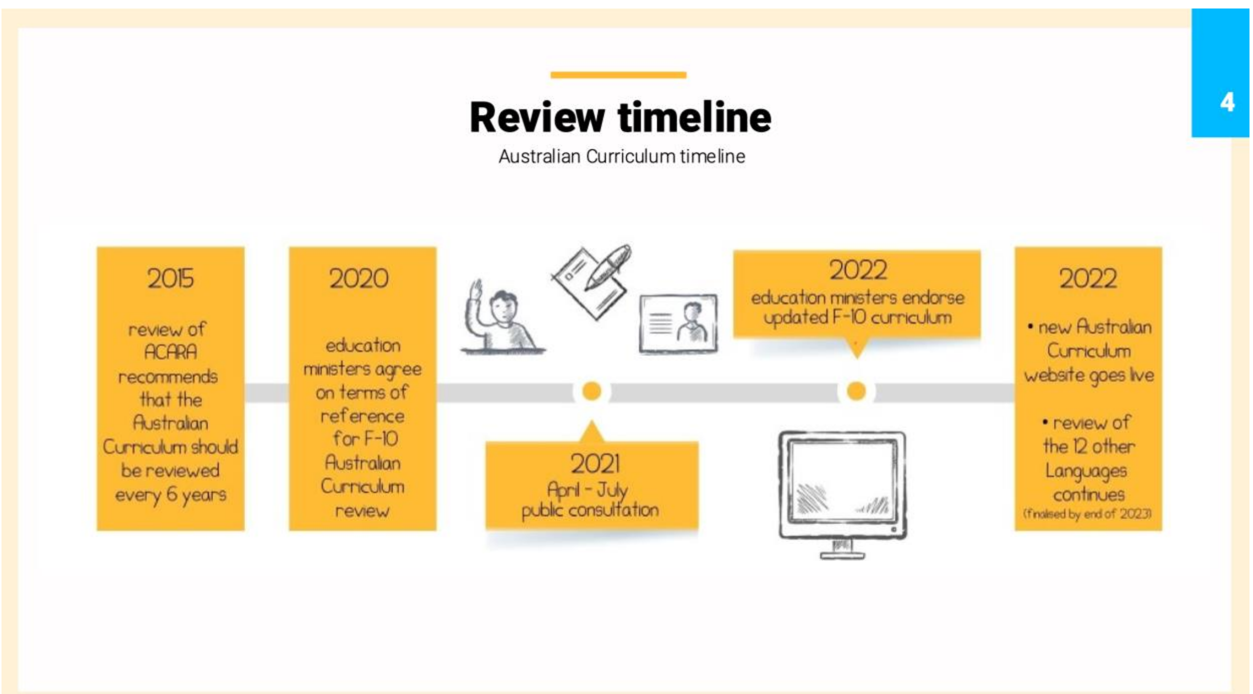
Today I am going to talk about that and how it relates to STEM education.

The structure of my presentation is as follows:

1) Background, process and timelines for the Review
2) What the data tells us about the state of STEM education
3) How the new AC could help address these issues: Specific changes to Maths, Science and Technologies
4) The role of STEM in developing the general capabilities of Critical and Creative Thinking and Ethical Understanding
5) Conclusion: how to get more young people studying STEM subjects – the power of intrinsic motivation



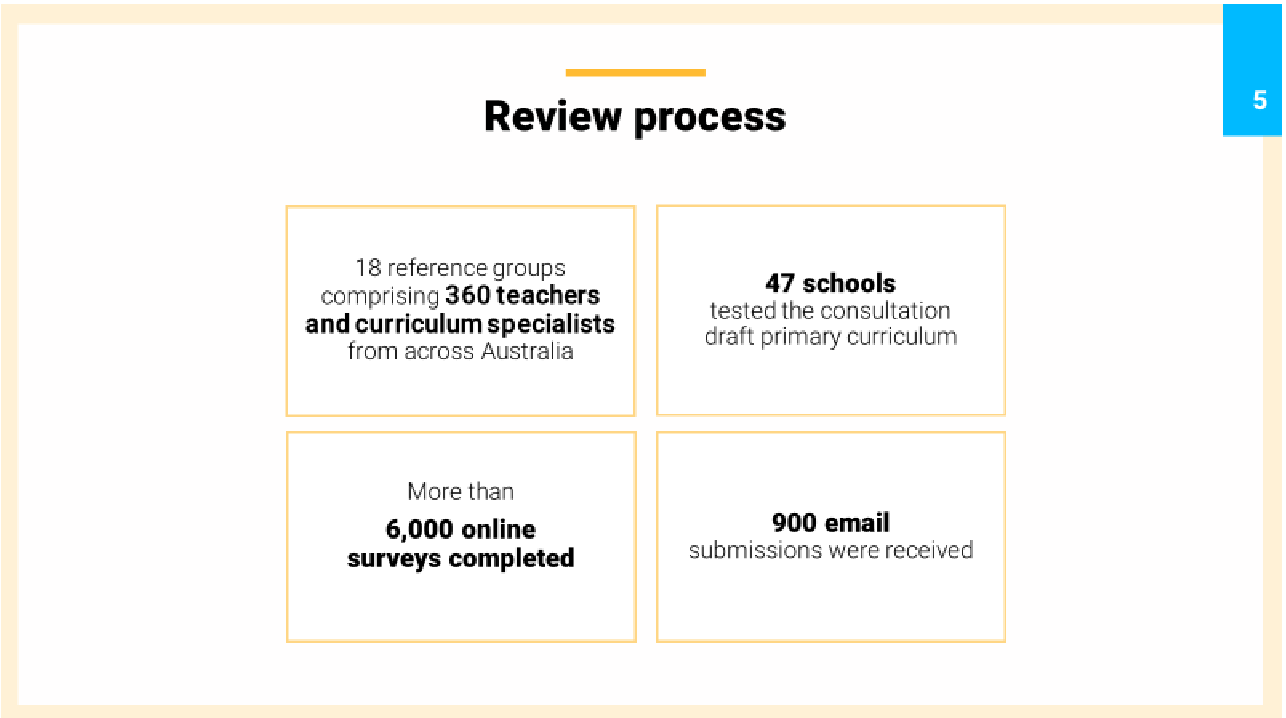
In 2015, Ministers agreed that the AC should be reviewed every 6 years. The last review was undertaken in 2014 so in 2020 Ministers gave ACARA ToR for a review and asked to complete the review by the end of 2021.



When we released a consultation draft of the Australian curriculum last April, it was the first time that such a draft had been open to the public as one document for feedback.

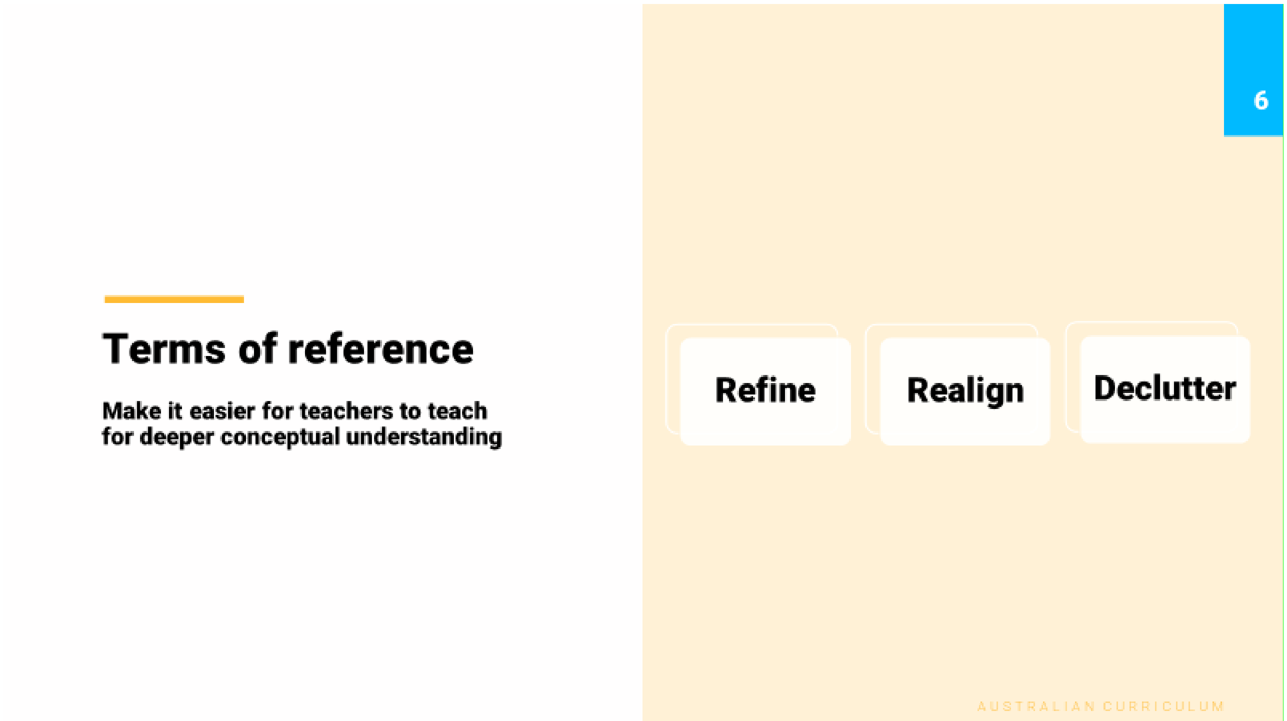
On the basis of the feedback we made substantial changes to the final draft that was eventually endorsed.

So the consultation we did with the community and with the teaching profession was essential and influential. The Australian Curriculum must represent broad community consensus and be based on well-informed and researched evidence.



Thousands of online surveys were completed and email submissions received, with the Aboriginal and Torres Strait Islander Histories and Cultures cross-curriculum priority, English and Mathematics receiving the most attention.

We also had detailed written feedback from all jurisdictions and sectors and our Primary School Intensive program meant we had 47 schools road-testing the draft curriculum to ensure it was manageable.

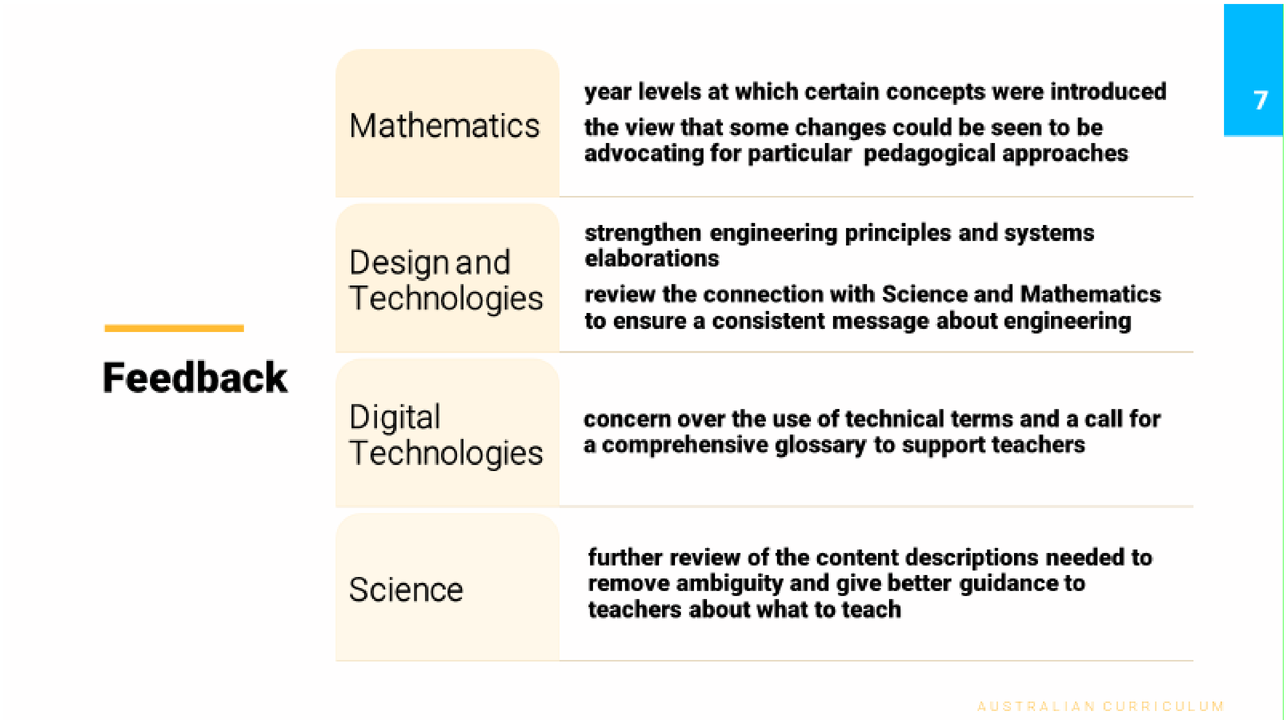


Our driving focus through the consultation was the direction from the terms of reference, which asked us to **refine, realign and declutter** the curriculum, which meant substantially reducing the amount of content to make it more teachable, and so teachers could linger longer on particular topics to ensure deep conceptual understanding, not just surface knowledge a large number of facts.

Feedback on the consultation draft confirmed that the proposed revisions for each learning area were an improvement on the current Australian Curriculum, Version 8.4:

- the introductory sections were more helpful,
- the content had been reduced, and
- achievement standards and content descriptions had improved in their clarity across all learning areas.

But - it wasn't all positive. There was **further** work to be done to reduce and refine curriculum content, especially in the primary years.

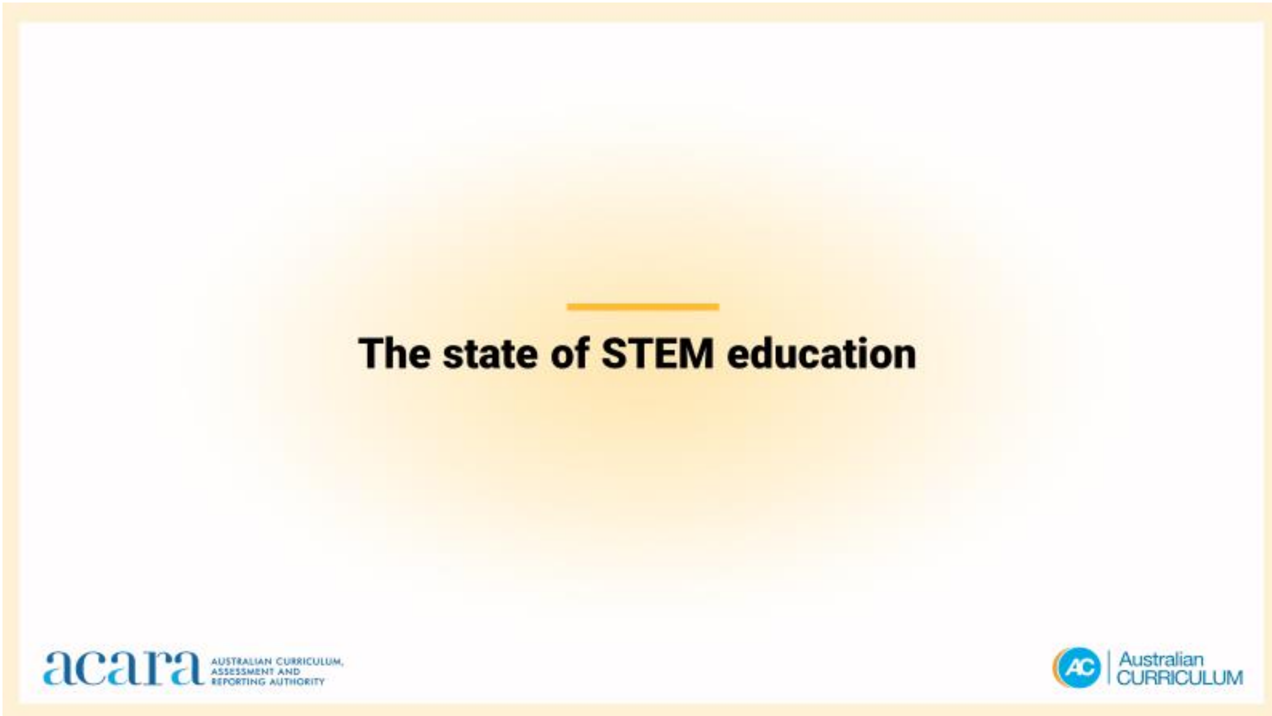


There was also a high level of feedback and public comment in relation to specific aspects that required further attention. These were:

- in **Mathematics**, there was concern with respect to the year levels at which certain concepts were introduced and the view that some changes could be seen to be advocating particular pedagogical approaches
- in **Design and Technologies**, a need to strengthen engineering principles and systems elaborations and review the connection with Science and Mathematics to ensure a consistent message about engineering across the curriculum
- in **Digital Technologies**, there was concern over the use of technical terms and a call for a comprehensive glossary to support teachers
- **in Science**, feedback indicated that further review of the content descriptions was needed to remove any ambiguity and give better guidance to teachers about what to teach.

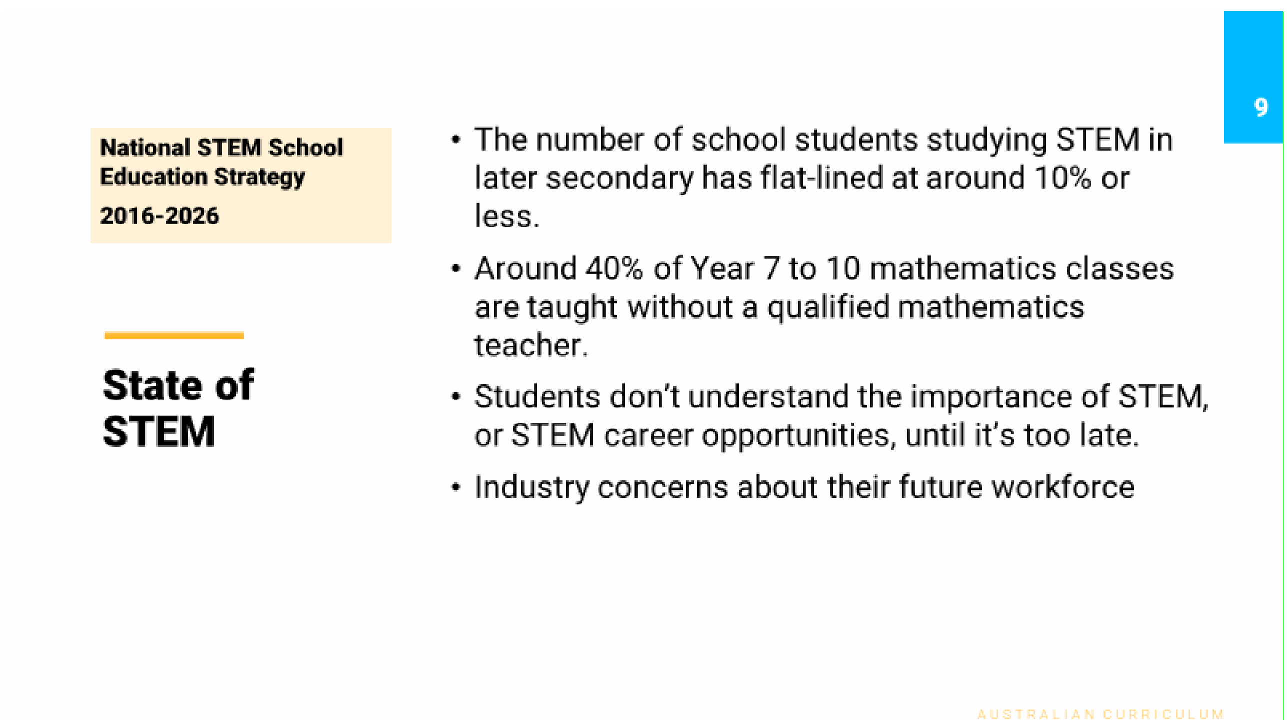
We listened carefully to that feedback to hear what the community and especially what the teaching profession had to say.

But before I go through the changes that we made, and give you some insight into what our hopes are for the curriculum when it comes to STEM, I want to summarise some facts about the current state of STEM education which we hope those changes will go some way to addressing.



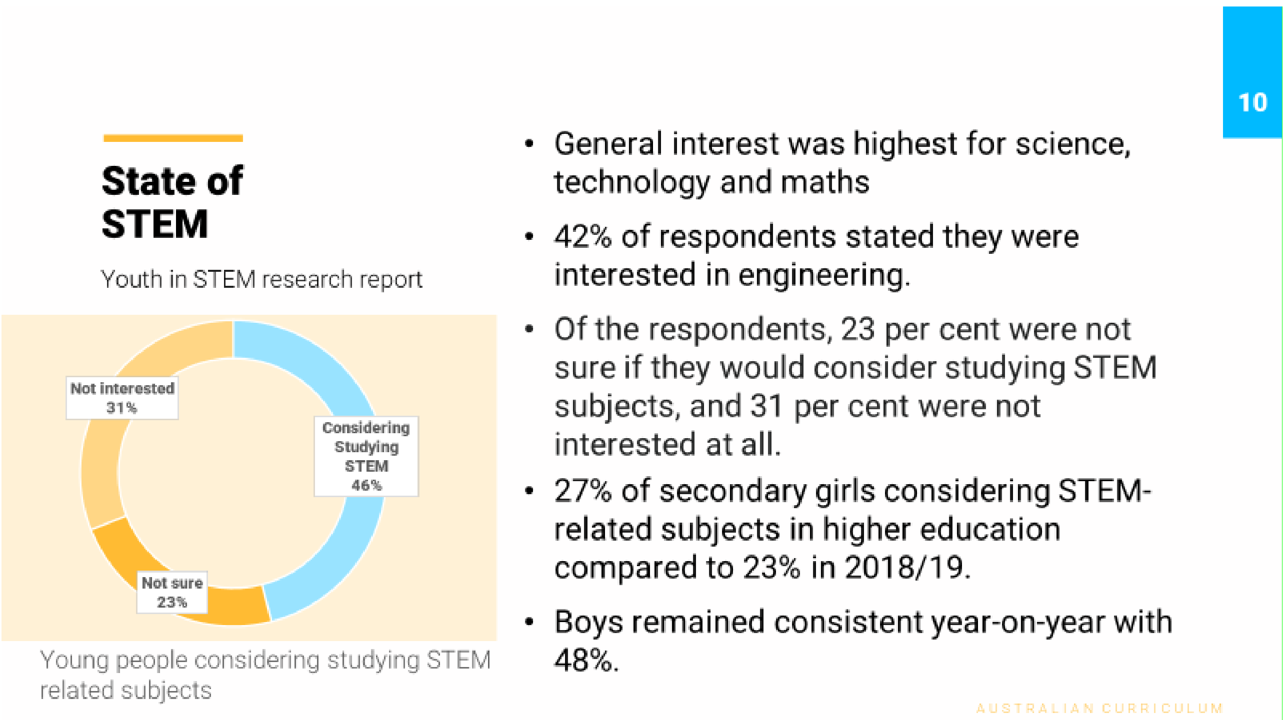
Interdisciplinary STEM learning can enhance students' scientific and mathematical literacy, design and computational thinking, problem-solving and collaboration skills.

Ensuring that all young Australians regardless of their background or postcode are able to participate in STEM has implications for their future employment opportunities and their contributions in an area seen as vitally important for innovation and our collective prosperity.



But there are many reasons to be concerned about Australia's STEM activity and what this means for our future. We know from the National STEM School Education Strategy 2016-2026 that:

- The number of school students studying STEM in later secondary (Year 11 and 12) has flat-lined at around 10% or less.
- Around 40% of Australia's Year 7 to 10 mathematics classes are taught without a qualified mathematics teacher.
- Australian students don't understand the importance of STEM, or STEM career opportunities, until it's too late.
- Employers are desperate for STEM graduates but have major concerns about skill shortages and recruitment challenges that risk the future of key industries.

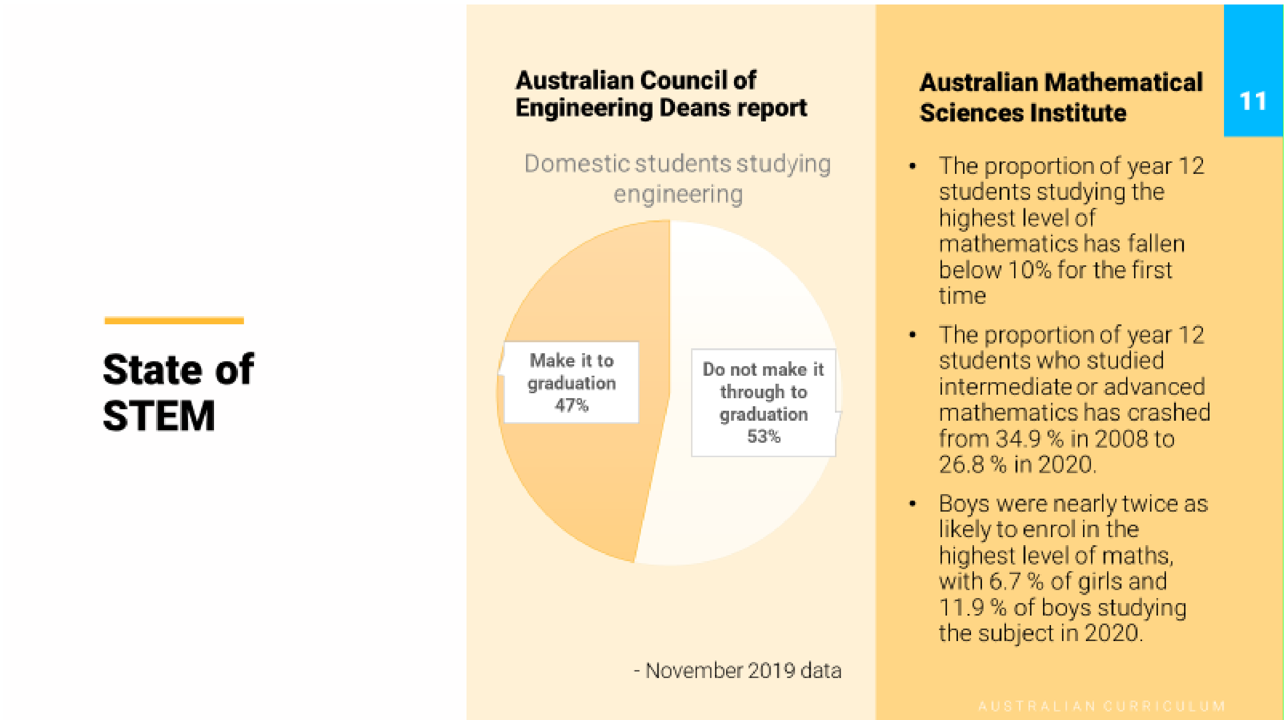


On the upside, we see from the 2019 **Youth in STEM** research report that there is a healthy level of general interest in studying STEM subjects. This was highest for science and technology (64 per cent and 65% respectively). 50 per cent of the 3000 young people surveyed indicated their interest and confidence in maths.

- Only 42 per cent of respondents stated they were interested in engineering. Engineering was found throughout the survey to be the subject where young Australians had the least confidence, understanding and interest.

- Of the respondents, 23 per cent were not sure if they would consider studying STEM subjects, and 31 per cent were not interested at all.

- Fortunately, however, there are signs of the gender gap beginning to close, with 27 per cent of Year 11 and 12 girls considering STEM-related subjects in higher education compared to 23 per cent in 2018/19. Boys remained consistent year-on-year with 48 per cent.



While we can see that there are some green shoots, data from the Australian Council of Engineering Deans report on Australian Engineering higher education statistics (2009-2019) shows that a significant proportion of students don't make it through to graduation.

November 2019 data indicates from the almost 15,000 domestic students studying engineering, only around 7,000 students make it to graduation.

What this means is we are very dependent on skilled migration to fill that gap, rather than growing our own.

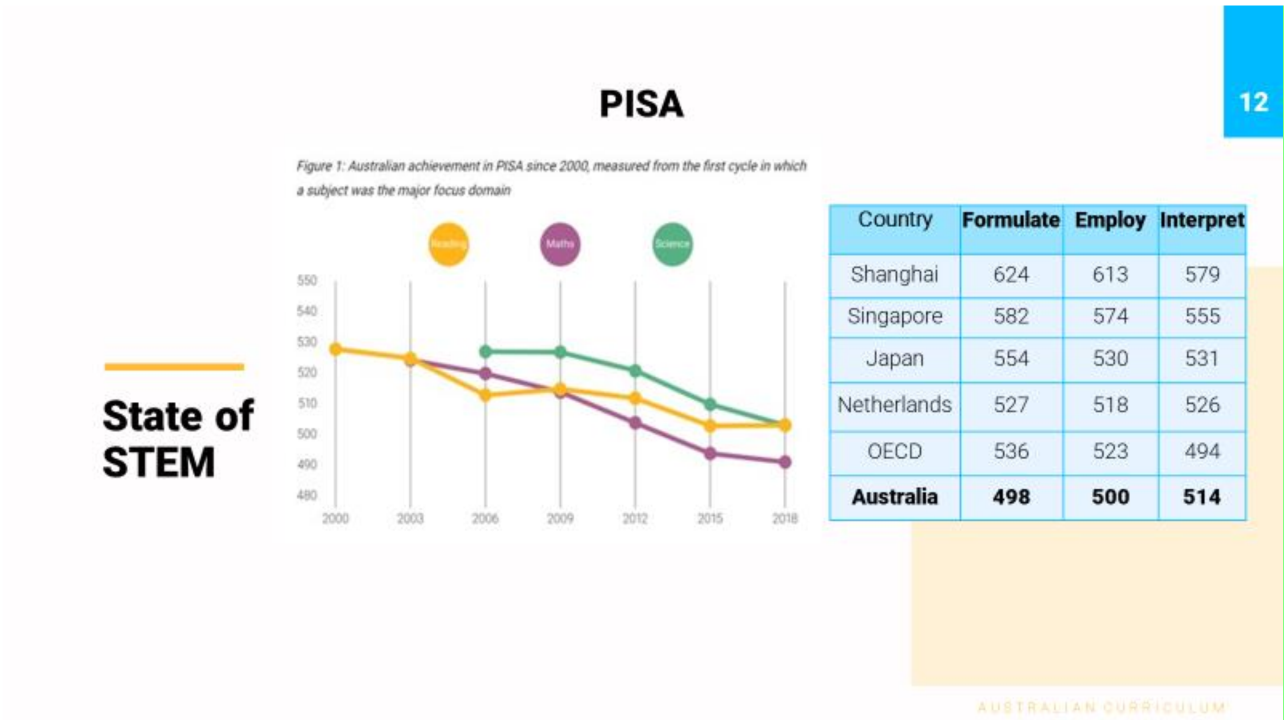
There are multiple factors influencing this phenomenon, but certainly one of them is the high level of mathematics required to succeed in the discipline and finding appropriate academic support.

Research from the **Australian Mathematical Sciences Institute** shows a decline in students selecting advanced maths in senior secondary years, particularly girls.

Their research showed:

- The proportion of year 12 students studying the highest level of mathematics has fallen below 10 per cent for the first time

- Only 9.2 per cent of year 12 students enrolled in specialist maths in 2020, compared with 11.6 per cent in 2008, the AMSI report shows.
- Just 17.6 per cent studied intermediate mathematics in 2020 – down significantly from 23.3 per cent of students in 2008.
- Together, the proportion of year 12 students who studied intermediate or advanced mathematics has crashed from 34.9 per cent in 2008 to 26.8 per cent in 2020.



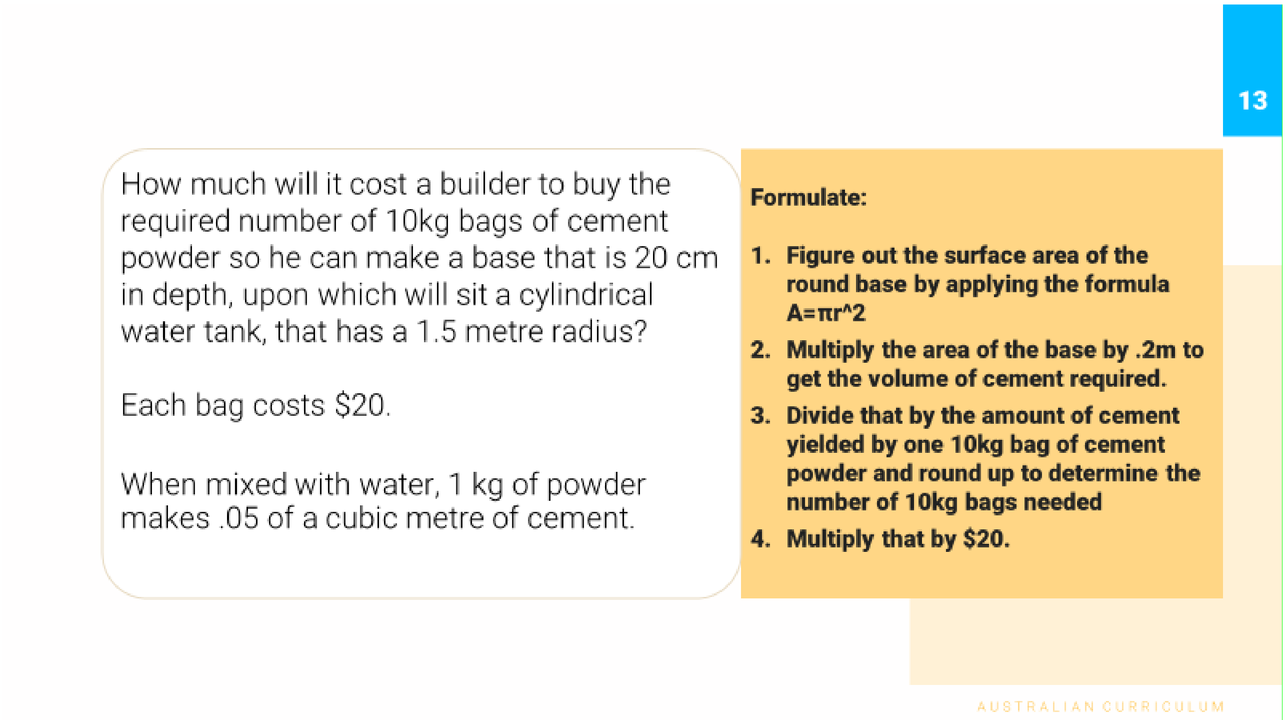
When it comes to our PISA results, Australia has continued to slip down the international ranking tables as other countries improve.

In 2003, 4 countries or economies significantly outperformed Australia in PISA mathematics. In 2018, 23 did.

If we look deeper at our PISA mathematics results, we can see that in terms of the three elements of the PISA mathematics framework, Australian students perform weakest in the “formulate” dimension compared to “employ” and “interpret”, whereas the highest performing countries performing most strongly in the “formulate” dimension. In other words, performance in “formulating” is where we really need to lift our game. But what does “formulate” mean?

Well, it’s actually the most crucial step in being able to apply mathematical reasoning to a real-world problem. According to the OECD PISA mathematics framework:

The word “formulate” in the mathematical literacy definition refers to the ability of individuals to recognize and identify opportunities to use mathematics and then **provide mathematical structure to a problem presented in some contextualized form**. In the process of formulating situations mathematically, individuals determine where they can extract the essential mathematics to analyze, set up, and solve the problem. They translate from a real-world setting to the domain of mathematics and provide the real-world problem with mathematical structure, representations, and specificity.

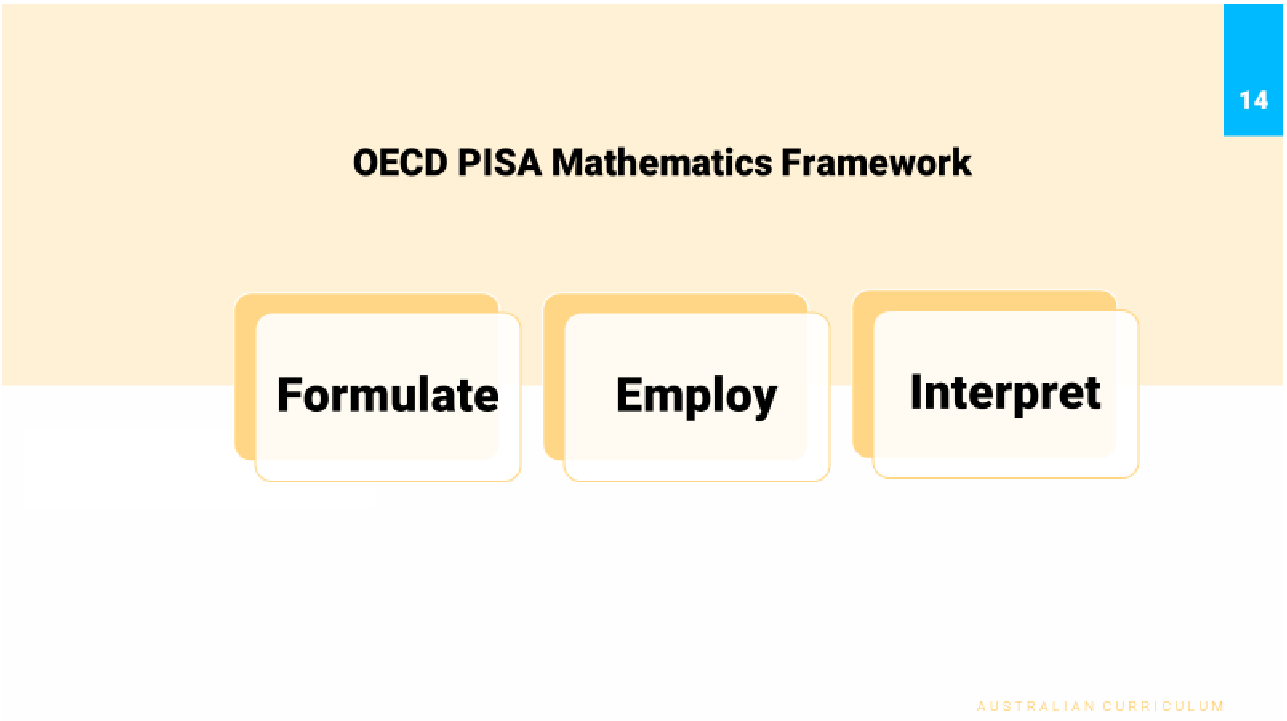


For example, let’s imagine this question:

How much will it cost a builder to buy the required number of 10kg bags of cement powder so he can make a base that is 20 cm in depth upon which will fit exactly a cylindrical water tank that has a 1.5 metre radius? Each bag costs $20. When mixed with water, 1 kg of powder makes .05 of a cubic metre of cement.

The “formulate” skill is the ability to recognise that this problem can be expressed mathematically in the following way:

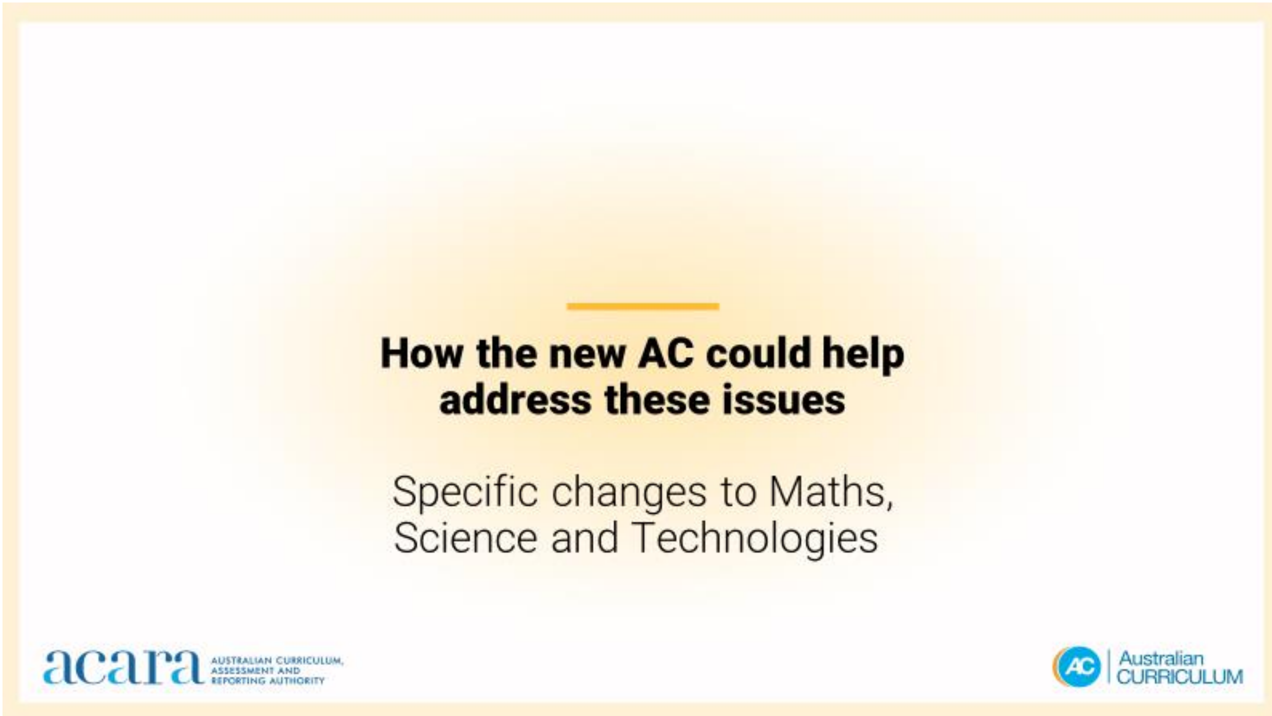
- Figure out the surface area of the round base by applying the formula $A = \pi r^2$
- Multiply the area of the base by .2m to get the volume of cement required.
- Divide that by the amount of cement yielded by one 10kg bag of cement powder and round up to determine the number of 10kg bags needed
- Multiply that by $20.



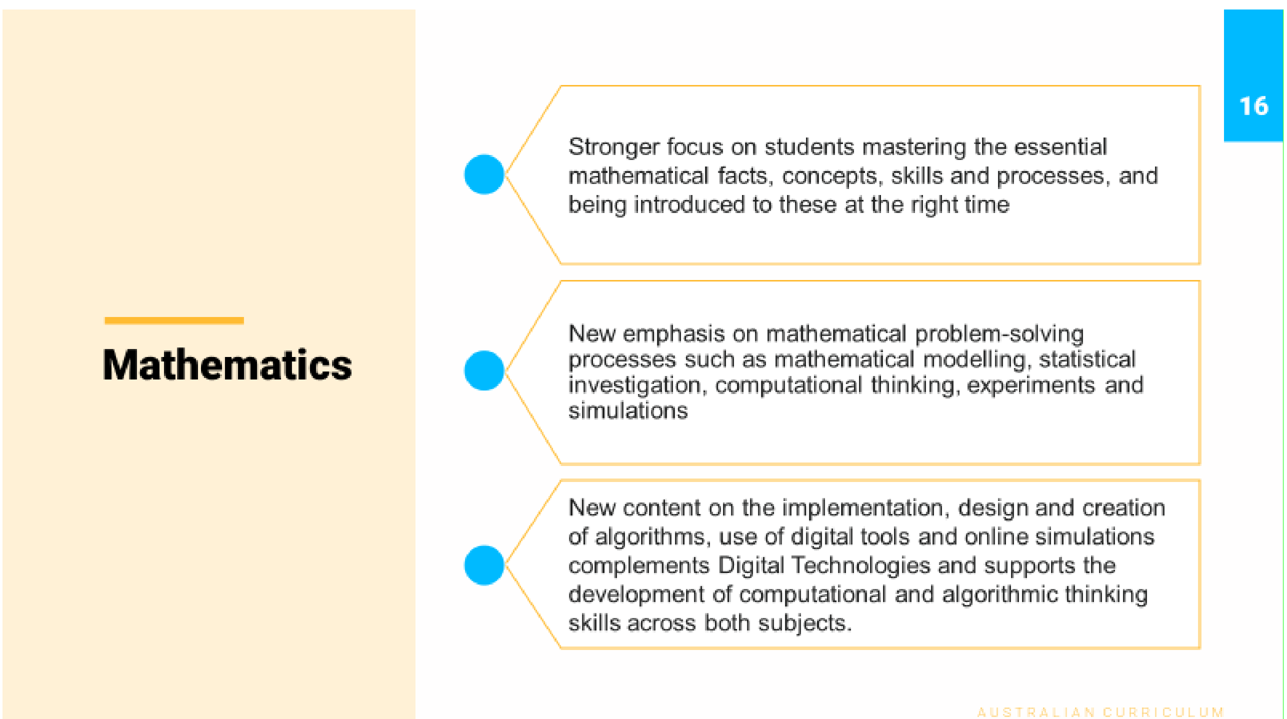
Australian students are relatively weak in the ability to do this kind of thinking compared to high-performing countries, and it is the weakest of our three capabilities. We are better at “employing” and “interpreting”.

In other words, we are good at knowing what the rules of Mathematics are and how to do the associated calculations, relative to understanding the reasons for those rules or knowing when to apply them.

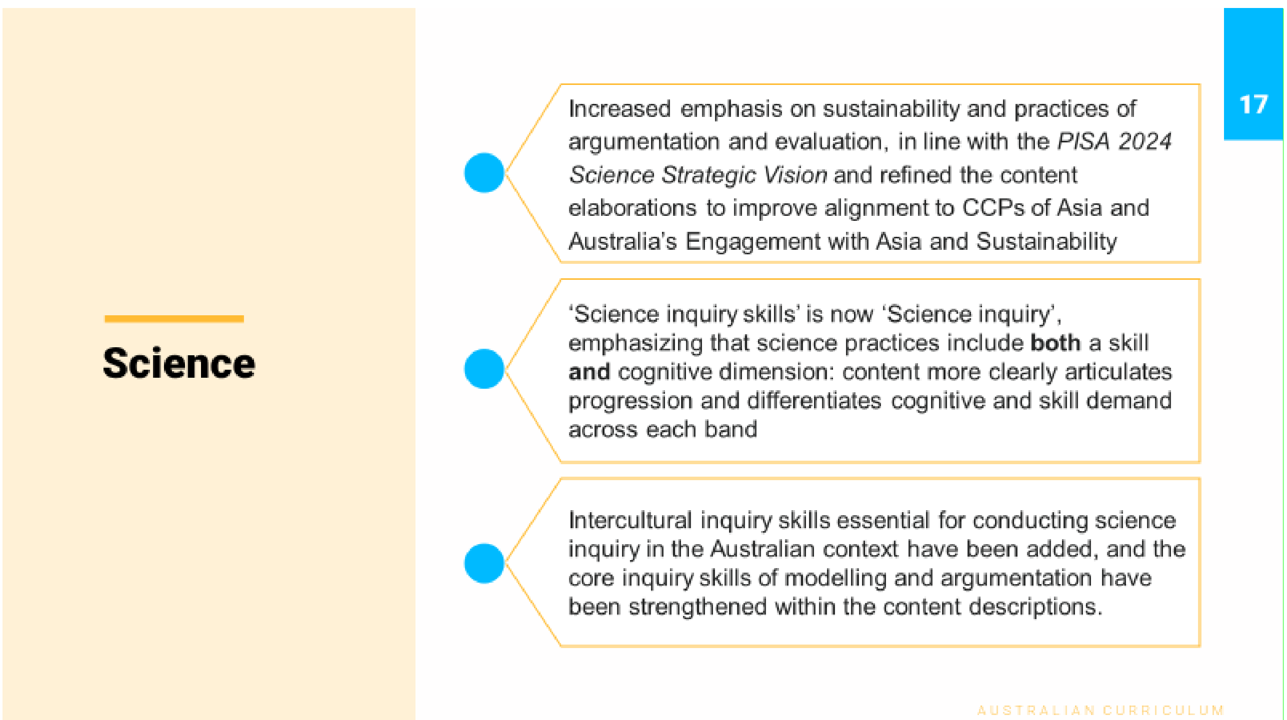
This is an issue we have tried to address in the new Australian Curriculum.



So let's look now at some of the key changes in Maths, Science and Technologies that we think should go some way to addressing these various problems. In response to the extensive feedback we received, we made further changes to the draft curriculum before presenting it to Ministers. In relation to…



- We have a stronger focus on students mastering the essential mathematical facts, concepts, skills and processes, and being introduced to these at the right time
- We make it clearer what mathematical computations need to be done without a calculator, reinforcing the importance of becoming proficient in foundational skills.
- There is a new emphasis on mathematical problem-solving processes such as mathematical modelling, statistical investigation, computational thinking, experiments and simulations; providing real-world problems for students to grapple with, where they choose what maths to apply (formulate) and how to apply it (employ) in terms of the situation (interpret)
- In the new **Mathematics** content, the implementation, design and creation of algorithms, use of digital tools and online simulations are an integral part of a computational thinking approach to learning and experimenting in mathematics; it now complements Digital Technologies and supports the development of computational and algorithmic thinking skills across both subjects.



Science provides opportunities for students to develop an understanding of important science concepts and processes, the practices used to develop scientific knowledge, science's contribution to our culture and society, and its uses in our lives.

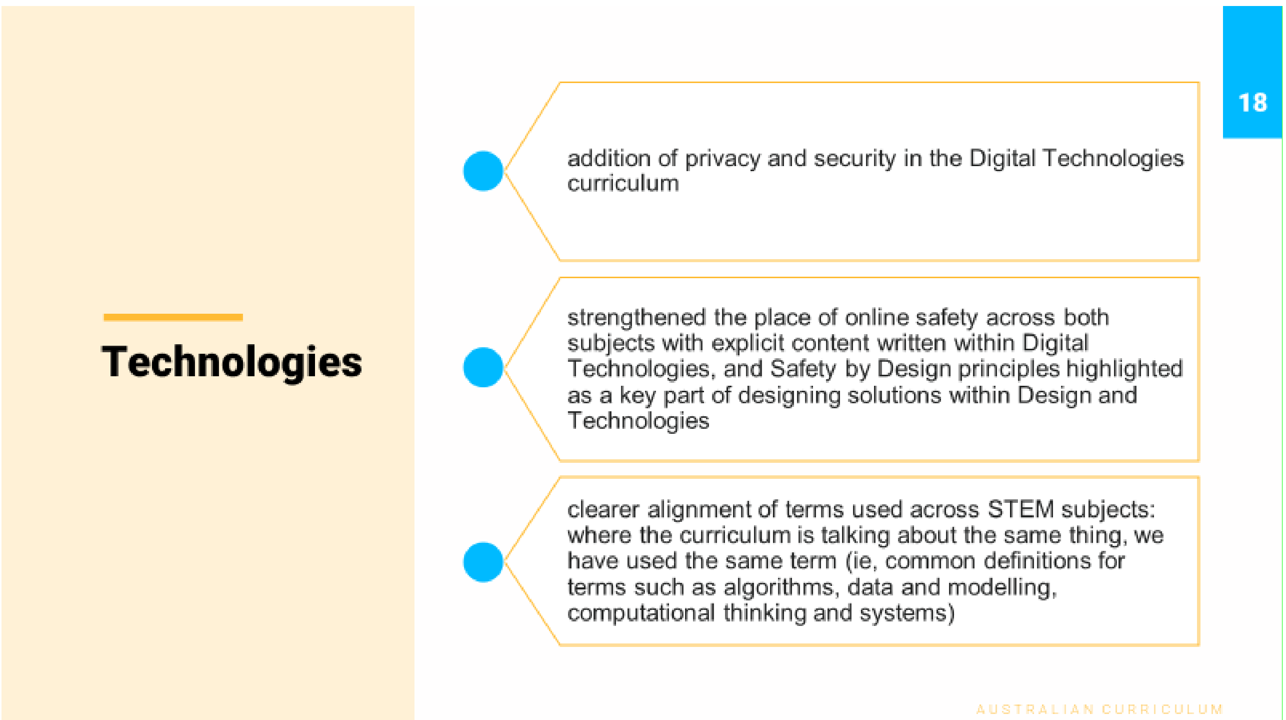
This supports students to develop the scientific knowledge, understanding and skills needed to make informed decisions about local, national and global issues and to succeed in science-related careers.

In that context, there is an increased emphasis on sustainability and practices of argumentation and evaluation, in line with the PISA 2024 Science Strategic Vision and refined the content elaborations to improve alignment to CCPs of Asia and Australia's Engagement with Asia and Sustainability.

‘Science inquiry skills’ is now ‘Science inquiry’.

This is in line with international trends and emphasises that science practices include **both** a skill **and** cognitive dimension. In the Science inquiry strand, content has been refined to more clearly articulate progression and differentiate cognitive and skill demand across each band.

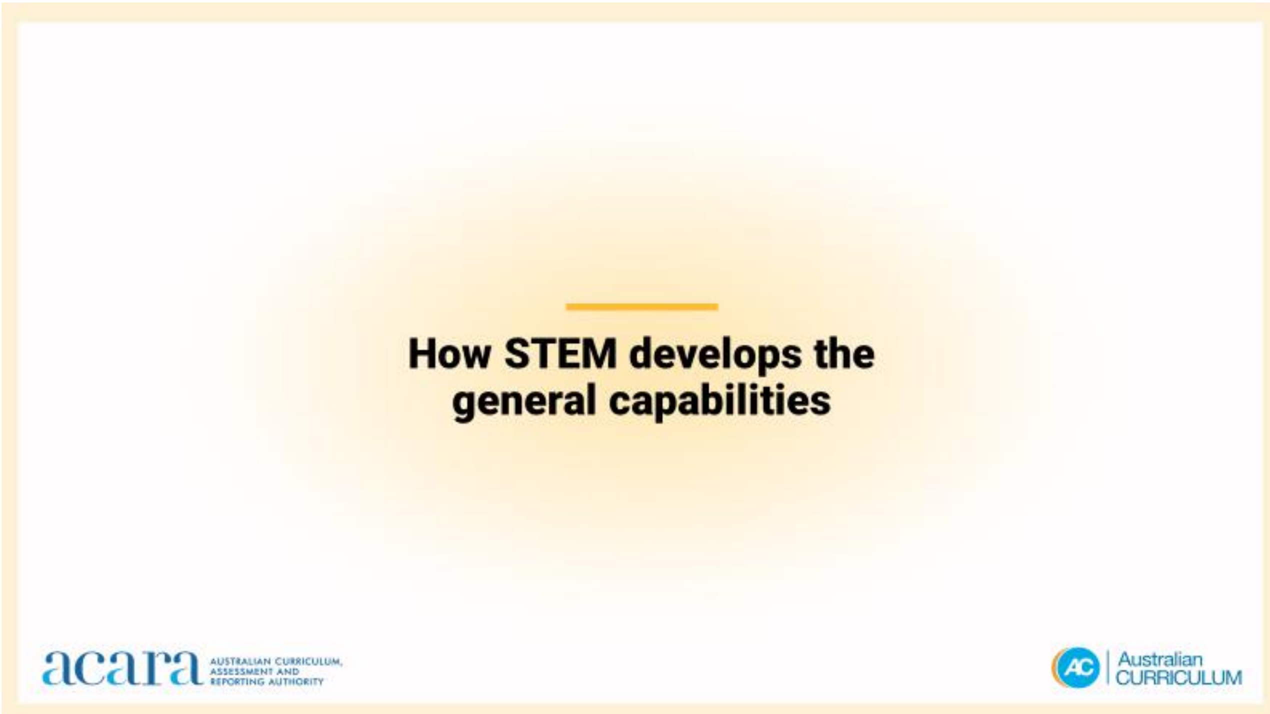
Intercultural inquiry skills essential for conducting science inquiry in the Australian context have been added, and the core inquiry skills of modelling and argumentation have been strengthened within the content descriptions.



- There is the addition of privacy and security in the Digital Technologies curriculum, and
- We have strengthened the place of online safety across both subjects with explicit content written within Digital Technologies, and Safety by Design principles highlighted as a key part of designing solutions within Design and Technologies.
- One very important change is that there is now much clearer alignment of terms used across STEM subjects. Where the curriculum is talking about the same thing, we have used the same term. For example, terms such as algorithms, data and modelling, computational thinking and systems have common definitions across Science, Technologies and Mathematics.

This makes it easier for students to transfer their learning across learning areas, which can lead to a better conceptual understanding of the relationships between the STEM disciplines.

Our changes have strengthened connections teachers can make across STEM subjects and have provided opportunities for a richer and more authentic learning experience.

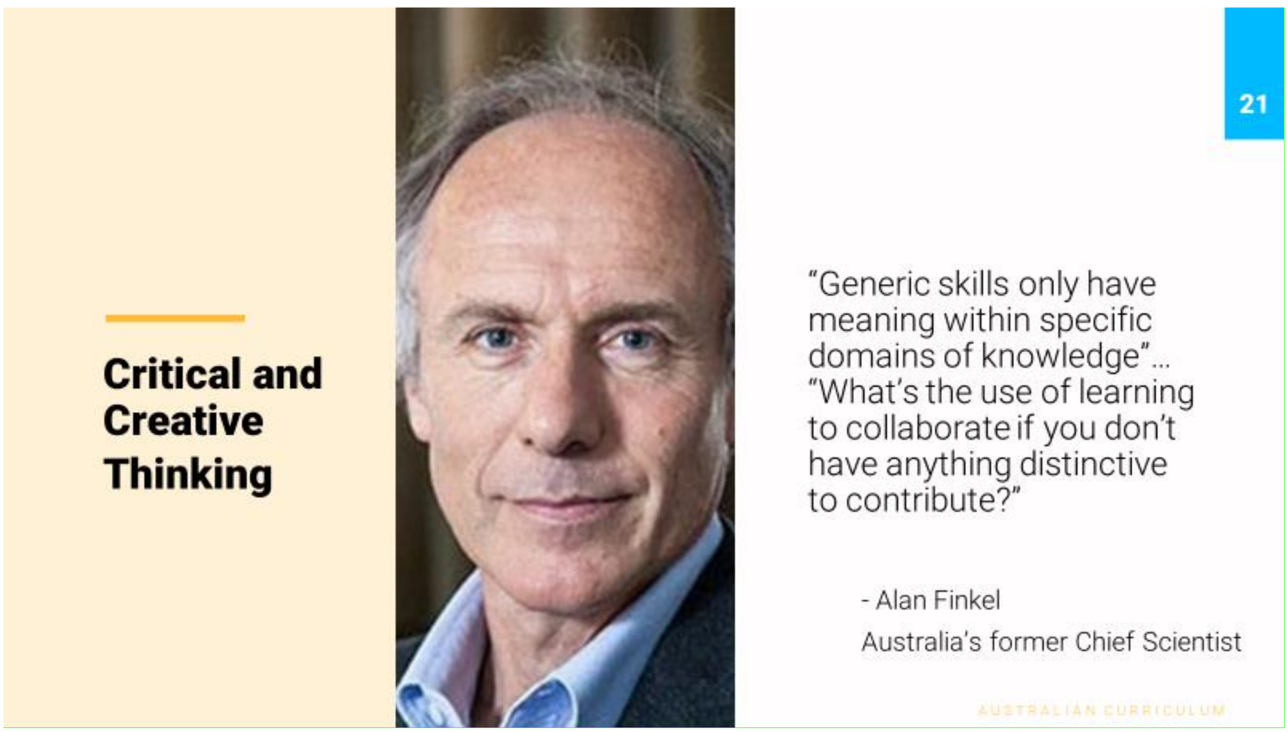


As part of the review, we clarified the relationship between the three dimensions of the curriculum. We wanted to be clear that learning areas have primacy of place in the curriculum. It is through them that the general capabilities are developed.

The general capabilities and the cross-curriculum priorities are best taught by being integrated appropriately and authentically into the teaching of the learning areas, not as separate “add-ons” that would contribute to an over-crowded curriculum.

Not every cross-curriculum priority and general capability can be addressed in every learning area. Some learning areas are better suited to the development of particular capabilities than others. For example, digital literacy as a general capability is obviously more at home in Technologies that in English.

One of the educational debates over recent years is a false dichotomy between those who say the curriculum should focus on knowledge rather than capabilities, lining up opposite those who say we need to focus on capabilities because facts can now just be looked up on the Internet. We need to avoid perpetuating such a simplistic false dichotomy between factual knowledge and capabilities.



Critical and creative thinking is often the battleground over which this debate is fought out. But, as the former Chief Scientist, Alan Finkel was fond of saying: You can’t engage critically and creatively on a topic if you lack the relevant background knowledge. When you’re thinking critically and creatively, you’re thinking ABOUT SOMETHING.

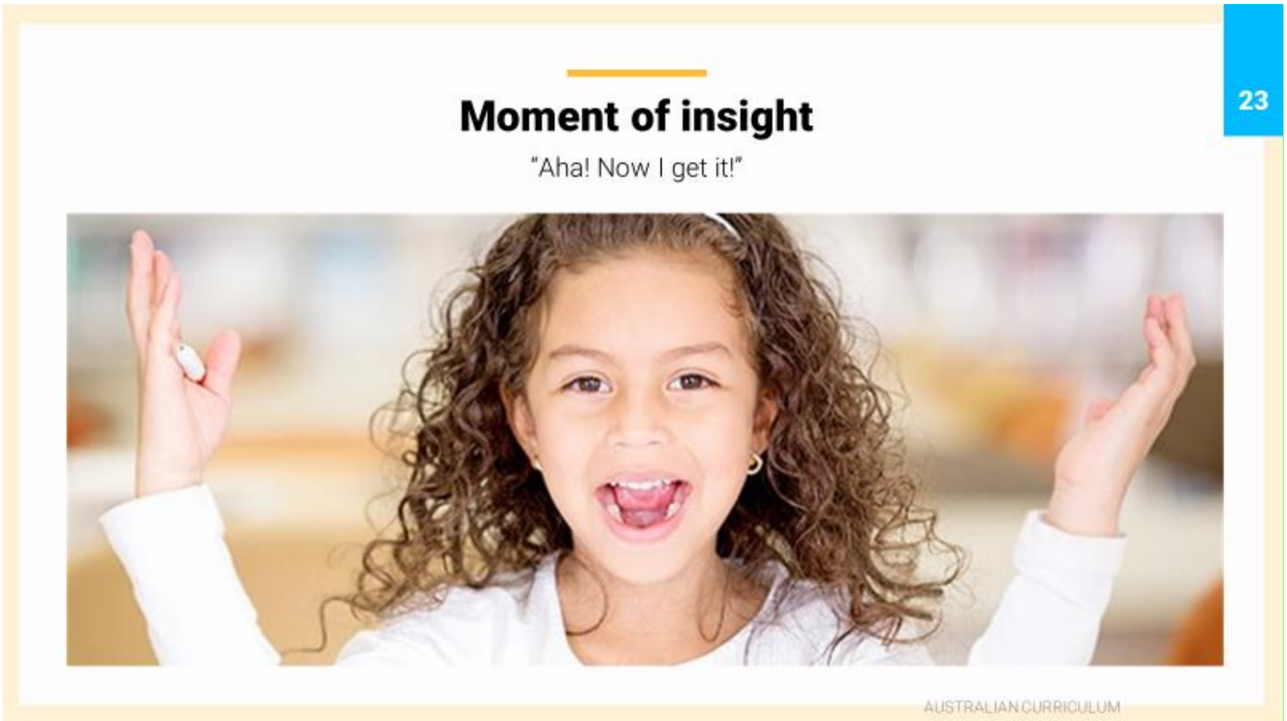
In "How People Learn", the US National Research Council stated that facts are important for thinking and problem solving.

> "Research on expertise in areas such as chess, history, science and mathematics demonstrate that experts' abilities to think and solve problems depend strongly on a rich body of knowledge about subject matter.
>
> "Research also shows clearly that 'usable knowledge' is not the same as a mere list of disconnected facts.
>
> "Experts' knowledge is connected and organised around important concepts (eg, Newton's second law of motion); … it supports understanding and transfer (to other contexts) rather than only the ability to remember."

But knowledge to serve critical and creative thinking and problem-solving it needs to be **appropriated** by the student, that is, understood.

A student may "know" Newton's Second Law of Motion, F=ma. They can "know" this simply by accepting it on trust from their teacher who tells them it is the case, and then memorising the formula. But do they understand it, and understand why that formula is correct and when they should apply it in different practical situations to solve real-world problems?

The joy of understanding, the joy of the moment of insight that comes from experiencing and **noticing for themselves and in themselves** that their knowledge of the world is expanding, this is not something that can just be had by memorising the formula told to them by the teacher. This joy of understanding is what makes learning exciting.



And it's what make teaching exciting. Seeing the look of excitement on the face of the student when they experience that "aha!" moment.

If we want our young people to be creative and critical thinkers and problem solvers, then it is crucial that factual knowledge about a topic is taught in ways that promote understanding.

Depth of understanding is built up over time, which is why, in the updated Australian Curriculum, we have had such a focus on decluttering so as to create more time for teachers to teach key concepts and facts in a way that deepens understanding and makes it possible to think critically and creatively about a topic and solve related problems.

Another general capability in the Australian Curriculum is ethical understanding, factual knowledge here is just as important.

Ever since Sir Francis Bacon, the father of modern science, declared that "knowledge is power" and that the role of science was to "torture" nature in order to extract its secrets, the issue of how human beings use their scientific knowledge and apply it in the form of technological power has been thrown into sharper focus.

Just because we CAN do something, does that mean we SHOULD do it? A fully rounded education needs to help students think through that question.

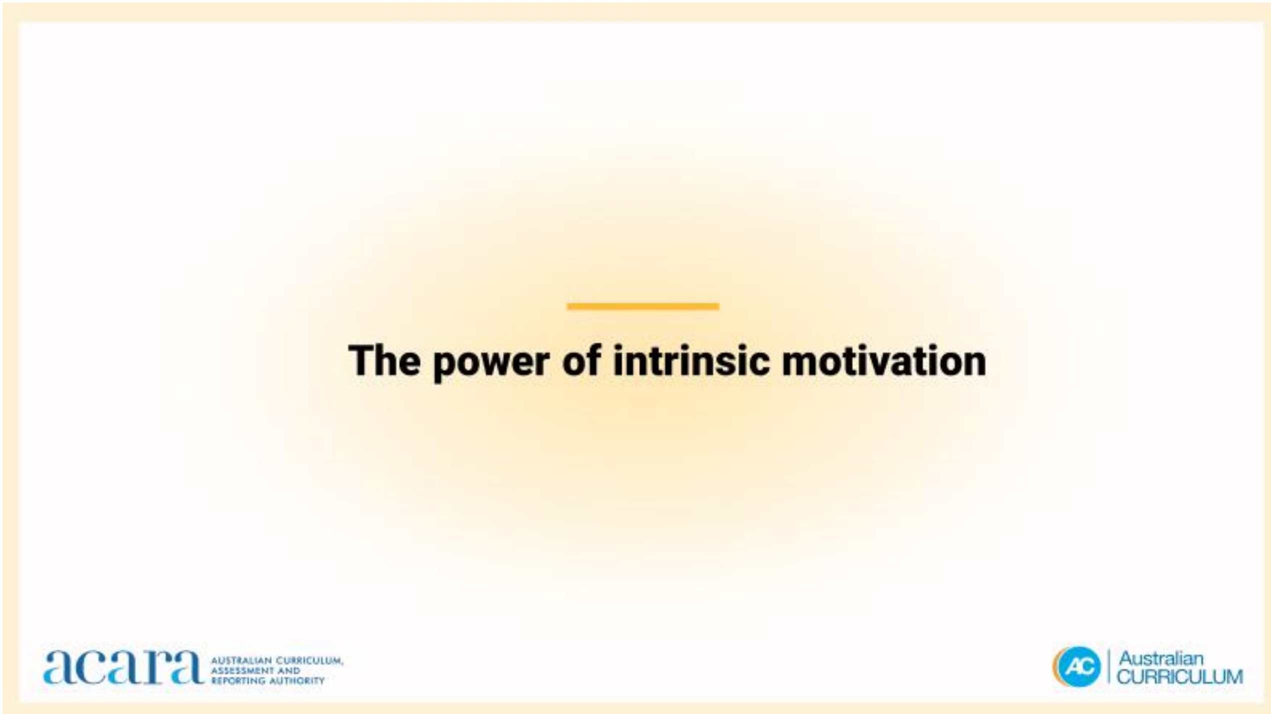
For example, think of the ethical dilemmas presented to those who discovered the explosive power of nuclear fission when it was realised that bombs could be built that could wipe out entire cities.

And what do we do with the scientific knowledge we have achieved about the damage being done to our own habitat by the application of technologies we have come to depend upon? If we knew then what we know now, would we have made different decisions?

So ethics is not only to do with the conduct of scientific research, but also with the uses to which its output is put. In July 2017, New Scientist Magazine published “The Ethics Issue” in which it posited the following ten questions:

In Mathematics as well, in the area of statistics, we need to help students to distinguish statistics from “damn lies”, by which we mean the unethical use of statistics and their presentation to mislead rather than inform.

These questions highlight the fact that STEM education should not just be about economic growth and employment opportunities. There are other important personal and social ends which need to be balanced with those goals. Which leads into my concluding remarks.



Developing knowledge and skill in the AC learning areas of Maths, Science and Technologies enables students to model, analyse and improve solutions to real-world problems, and it supports students to access further study and a variety of careers and jobs within or outside of STEM fields.

But how do we encourage students to take up STEM subjects, particularly higher-level maths and science subjects, in senior secondary schooling? The temptation here might be simply to say, as I have just done: “It will help you get a job.”

But the response of the sceptical teenager is likely to be: “Really? Is that it? Is that all you’ve got?” The question is legitimate and compelling, and cannot be avoided by blathering on about economic growth or some other abstract desideratum like technological progress.

It is vitally important that education is not seen exclusively through a utilitarian lens, as just being about getting a job, and being at the service of the economy or the national community more broadly. They are important outcomes of education, but at its most fundamental education is about the overall development of students as human beings and equipping them to fulfil those fundamental desires that are common to us all, our fundamental orientation towards what is true, what is beautiful and what is good.

It’s important to note that in the “Rationale” section of the Mathematics curriculum we state that “Mathematics has its own value and aesthetic.”

Aesthetics is associated with beauty.

In the Rationale for Science, we say "Learning science is a valuable pursuit in its own right. Students can experience the joy of scientific discovery. They can nurture their natural curiosity about the world around them."

Recently we had a reminder of the beauty of the world around them, a world more than worthy of their wonder, when pictures from the James Webb telescope were published by NASA.

Such images not only appeal to our aesthetic sense, but also to our sense of wonder, giving rise to a range of questions the meaning of what we are looking at. These photographs present a wonderful teaching opportunity.

Now teaching is a strange thing. It seems to be most effective when the student actually enjoys learning. By that I don't mean that every class has to be fun. Far from it. Learning can be fun, but fun is not necessary for learning. Learning usually involves struggle, but the tension of the struggle can be a source of joy, particularly when it is resolved in the moment of insight and understanding.

That pleasure is inherently private and the taste we acquire for more of it is intrinsically motivating. Yet STEM is generally promoted by reference to extrinsic motivations, such as employment and the economy. Those are useful motivational tools, but if that is the extent of our advocacy, it ignores the personal learning experience of the individual student.

The effort required to learn any subject well can be sustained only if the satisfactions are intrinsic, rooted in the activity of learning itself.

So what is really on offer, then, in a physics class? As Matthew B. Crawford has written:

> The math instils a taste for rigour, and through experiment one learns intellectual responsibility: facts often astonish theory and compel one to rethink one's position, starting anew from first principles. In its subject matter as well as its method, physics ennobles the mind by directing it to the permanent order of the world. One learns, first, that the world has such an order, and that it is intelligible. One can't help but feel that there is some deep harmony between the natural world and our efforts to understand it, or understanding wouldn't be so pleasurable.

But science and higher level mathematics which is its companion, are hard. Studying them could therefore be seen as inherently "elitist," merely in this obvious sense: some will be demonstrably better at it than others. This sits ill with the fetish for self-esteem.

We might be tempted to promote science and maths because they underpin many of the technologies that make our lives more comfortable. This is a legitimate approach, but if that's all we do, these efforts to popularise in a superficial way carry the implicit message that STEM subjects, and intellectual life more generally, must pass the test of financial and economic usefulness before we take them seriously.

According Crawford, one American textbook seeks to encourage the study of physics by giving, as an example of its usefulness, how modern razor blades give a smoother shave due to the use of ultra-thin films derived from plasma physics techniques. As Crawford says, "All true enough, but how drab, how utterly uninspiring."

Which is not to disparage the work of those razor blade engineers, but far from giving these subjects a wider appeal, this may merely dishearten students because it treats them as though they are insensitive to intellectual pleasures, this kind of anti-elitism seems strangely, and ironically, elitist, treating students as if all they are good for is assuming their place as workers and consumers.

Perhaps the way to encourage greater uptake of STEM, particularly maths and science, is to focus on how difficult and enjoyable they are to master, how intrinsically interesting and wonderful.

If that doesn't work, then we are in worse shape, culturally, than we might think (if we even think about this). But it might be the approach that appeals to the optimistic and rebellious spirit of our young people who want be inspired and liberated, not harnessed to the wheels of economics. So why not give it a go?

Let's make our classrooms places where students experience the interior and lasting joy of learning, regardless of whether we are having fun or whether that learning is "relevant" according to some utilitarian calculus.

The new Australian Curriculum will hopefully make this joy a more common experience in relation to the study of STEM subjects.