Policy Pitch – STEM for all - Melbourne

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Education commentators divide over how much to promote the disciplines now known as STEM: Science, Technology, Engineering and Mathematics.

- We hear that Australia's future productivity depends on our strength in the STEM disciplines. Yet in many of these disciplines, there are more university graduates than jobs for them.
- We hear that the future belongs to those with the skills to become the next Bill Gates or Mark Zuckerberg. Yet the proportion of young Australians who study science or maths to Year 12 is in long-term decline.
- We hear that Australia punches above its weight in research. Yet by the time students reach Year 9, more than one in three lack the scientific and/or numerical literacy they need to thrive. For students from disadvantaged backgrounds, the numbers are far bleaker.

Dr Peter Goss, Grattan Institute School Education Program Director, hosted an expert panel to explore these contradictions.

- Do all, or only some, young Australians need a strong foundation in STEM? What are the essential capabilities that make up this foundation?
- How well are we performing today? Which students are being well supported, and which are being left behind?
- What can we do to deepen and broaden STEM in schools so that every young Australian has the capabilities to participate fully in the modern world?

PETE GOSS: Thank you to the State Library for making this fabulous series possible, we do these roughly once a month, it's been going for a couple of years and it's very popular. Thank you all for coming out on a fairly cold night, luckily not too rainy a night, but it's nice, warm and welcoming in here and we have about 75 minutes together to explore what I find a fascinating topic. I'm only partially biased because that's where I started out my career. I'd also like to thank before we start the various Grattan affiliates who make our work possible, some of whom have a strong interest in STEM, one of whom in particular, BHP, has recently put a very substantial amount of money in to support mathematics for girls and women, which is fabulous.

I'd like to thank my panel members, so introducing we have Professor Ian Chubb who is Australia's Chief Scientist. He started that in 2011 and I believe has about seven months to go, so I suspect that there might be quite a large agenda of things that you would be hoping to get done this year. He has had previous roles including Vice-Chancellor of the ANU, Vice-Chancellor of Flinders University, and then working through he was appointed a Companion of the Order of Australia for service to higher education including research and development policy in pursuit of advancing the national interest. Anne Hampshire is Head of Research & Advocacy at The Smith Family. She has a background in education, research, social policy and service innovation and, I believe, along the way a Diploma of Education in mathematics teaching. Anne has written and researched in a range of areas and recently has contributed to The Smith Family's successful program for preschool children and families *Let's*

Count. Diane Siemon is Professor of Mathematics, Education and the School of Education at RMIT. She's a past President of the Australian Association of Mathematics Teachers and a life member of the Mathematical Association of Victoria. When I first spoke to Diane she spoke about the big ideas in number and this was something that really grabbed my attention and I'm hoping that we can learn some more about. So we have a very expert panel, could you please welcome Ian, Diane and Anne.

So before we start with the questions I think it's important to put a bit of context in order. I did a Google search just before I came down here on "Australia report STEM" in the last year. I found "benchmarking of Australian science, technology, engineering and mathematics" in November 2014, Office of the Chief Scientist; I found "STEM country comparisons", comparisons of how well the different countries work through this; from the Australian Industry Group, "progressing STEM skills in Australia"; from PWC, "futureproofing Australia's workforce", what are some of the challenges as computers and technology takes over some of the current roles; from Swinburne, "creating a pipeline of STEM skills for the digital economy"; and then one on the Australian Mathematics Science Institute on "engaging more women and girls in mathematics and STEM fields".

This is an area that's becoming hot. We heard something about it last week in both the Budget and in the Budget Response, but it's not uncontroversial. An article today in The Australian by Judith Sloane said, "In some circles, STEM is now the new black. Investing more in science, technology, engineering, maths leads to a high productivity, high wage outcome inevitably, or so the thinking goes" but she then goes on to critique it and say, "Actually, maybe there are more STEM graduates than we need". So this is an area that does have some controversy and what I would like to do with our panel tonight is explore the question less so about what STEM capabilities do we need for those people of us who will choose to specialise in either science or technology or engineering or mathematics for their careers, but for the broader population. The world is changing, as we know, and I'm keen to understand do all or only some young Australians need a strong foundation; how well are we performing today; and what can we do to both deepen and broaden STEM?

So those are the themes that we'll explore through, I'll make sure that there's plenty of time for questions at the end. Thank you for those who have submitted questions beforehand, I've been able to weave about half of them into the panel area, and that's how the evening will run. So the broad benefits of STEM. Let's start the discussion at the top, thinking about the broad impact of STEM on society. Economists distinguish between creating new knowledge, adapting existing ideas and using technology productivity.

Ian, should we care as a society about STEM? Can't Australia just be the world's mine and food bowl, make fantastic coffee, celebrate when we win the World Cup, and borrow from others in the technology space?

IAN CHUBB: Well, there are some who would doubtless like us to do that. I wouldn't like to be in that position in 25 years' time when the world has moved a long way away from where that would place us. I should say right now, by way of introduction, that Judith and I have never agreed on anything and so I'm pleased to see that she doesn't quote me favourably today. One of the things that, for me, is just so simple I can't understand why it's a debate, that every person in this room, every person out there, Judith, will doubtless have used a smartphone today, probably taken some pharmaceutical for some physiological ailment, blood pressure, whatever it might be, aspirin, whatever it is, would have

cooked with something, eaten something, done something; everybody would have had science impinge on their lives today, several times today.

As the future unfolds before us, unpredictable as it might be with any great degree of precision, we can predict that it will be different from the past and I think that we should make sure that we factor that into our discussions. But as the future unfolds we will want an informed citizenry making informed decisions when they've got choices, and they will have choices. Genetically modified food, there will be a choice. It needs to be explained, it needs to be explained in a way that people can access the information without being expert, but with enough scientific literacy to understand how science works, what it might mean, how the discussion flows. Doubtless renewable energy technologies will become a big focus of debate. Australian citizens will need to make a choice and you would hope that those choices are better informed because there is a fundamental level, a reasonably high level of scientific literacy across the entire community embedded within which a few people who are real experts in subject areas.

So not everybody has to be an expert, but everybody needs to understand, in my view.

PETE GOSS: Thank you and that implies the question in some ways of how broadly should we categorise this? One of the audience members asked whether STEM should include geography because of the spatial technology skills it brings. Other countries include arts and call it STEAM, science, technology, engineering, arts and mathematics. How broadly should we think about STEM?

IAN CHUBB: Well, I'm for broad in that I believe that we can't have and see science on its own or technology or engineering or mathematics. All of them operate within an environment, within a context. That context is people and people need to be able to embrace what scientists are telling them is going to be good for them.

I'm reminded very much of a speech that I read, one of the best speeches that I've read, about 2002/3 from Tony Blair when he was Prime Minister in Great Britain and gave a speech to the Royal Society – and I've used this quote before, so I apologise to anybody who's heard it before, but it's very important. He said, "Science lets us do more but it doesn't tell us whether doing more is right or wrong" and he went on to talk about moral judgment, involving the community in the judgments that are made and so on, but to get the right decision out of that, which is an informed decision, then there has to be a level of understanding of science, how it works, why it's not wrong to see two scientists having an argument about something. It doesn't mean that that's not science at work. It is science at work and the scepticism that comes with good science where you don't take much at face value, you're always looking for a better way to explain the information, the data use, generate the data, whatever it might be.

So I do believe we have to contextualise it, I do believe it's incumbent upon scientists to work hard within their community to draw the community with them, but I think it's also incumbent upon us as a community to say that in order to do that properly we need to elevate the basic level of scientific literacy somewhere substantially higher than it is right now.

PETE GOSS: Very good, and I've no doubt that the rest of the panel would join me in agreeing that STEM is not the only thing that we need in education. I personally got the benefits of an education in classics and maybe another night we'll have a humanities for all equivalent to this because these

things complement. Let's have a look at why STEM might matter to people in different situations. I'm going to move onto Diane and ask what about students who are going to take courses at mathematics or TAFE that don't directly involve STEM? You've been a mathematics educator for many years; does everyone need calculus or algebra? What skills do we want people to have?

DIANE SIEMON: Well, I'll agree very much with Ian, I think it is absolutely fundamental that everyone has a good grounding in mathematics, mathematics is obviously my background, and it's not just for all the reasons Ian said. It's about opportunity. We will come to talk about where we're at at the current stage and where we're at with opportunities in mathematics in secondary school, but far too many people in our country simply do not have the options to explore other jobs and possibilities. I read the Price Waterhouse report and the biggest need is actually tradies and techies and no-one can possibly imagine that you can be a tradesman in today's economy without having a very significant broadly based understanding of mathematics but not only of mathematics, of physics and chemistry as well. And, as I said, to me it's about equity, it's about opportunities. No, not everyone needs to study integral calculus, but everyone needs a good understanding conceptually of what happens when things go to limits.

Now you don't need to be able to calculate, but you need to have an appreciation. Growth in the marketplace, population growth; to even understand newspaper reports and appreciate that when rates are to the power of something, I mean, that's about understanding how numbers work and what they mean and increasingly all our sources of information will be digital and those digital information will be pictures, it'll be graphs, it'll be numbers. The greatest numeracy demand is not calculation. The greatest numeracy demand is actually being able to read and compare numbers. It sounds very simple, but I don't know whether people remember, I think it was an Etihad jet that had a tail strike at the Tullamarine Airport. That was because a very experienced pilot mis-entered a digit in the hundreds place by one, but it meant that he was out 100 tons in his fuel supply and the plane was much heavier than he anticipated. There are many stories in medical situations where people are misunderstanding what a 1% solution might mean and one very real case that I'm aware of where someone was about to apply a 10% solution thinking it was 1%. So it's quite simple mathematics, but it can be quite life-determining.

So everyone I think absolutely needs a very good grounding not necessarily in the skills that computers and digital resources can do, but in a conceptual base, in bringing about a knowledge and a confidence, being able to solve problems, looking at things in different ways from different perspectives. Mathematics and science can do that, they can build investigative skills and creative skills and communication skills, and all of those are going to be needed. The Price Waterhouse report is actually quite alarming if you think about some of the statistics they're quoting. They're arguing that 44% of the workforce, which is about 5.1 million people, are at risk in employment from what they call "digital disruption". Now that's actually very significant, that places a huge demand on education, not just schooling but throughout the entire economy. And they also claim that just shifting 1% of the workforce, just 1%, 125,000 people at the current time, into STEM roles with some sort of retraining could generate up to $57 billion over 20 years at net present value. I mean, that's phenomenal.

Everyone needs it. We don't even know the jobs that are going to be coming. They are going to be in STEM fields, I think there's a figure in the Chief Scientist's report that something like 75% of the new jobs that will be generated are in the STEM field and currently we have a very, very low percentage of

females participating in those jobs. It's an equity issue. Everyone needs mathematics, but it's not the mathematics of yesteryear; it's the mathematics that's conceptual, that's rich, that's problem solving, that enables creative and critical thinking.

PETE GOSS: Very good and I heard about a range of different careers in there including pilots, including doctors. Let's drill down on that. A fair number of students are very disengaged from science at school and mathematics or even in school in general, nearly 15% of 20-24 year olds won't complete Year 12 or equivalent and some data from overseas suggests that 1 in 8 young Australians doesn't have the level of scientific literacy that they need to be productive citizens in the 21st century. Anne, this is the group of students that The Smith Family is trying to support, right?

ANNE HAMPSHIRE: That's right.

PETE GOSS: What happens if a student graduates Year 12 or equivalent and goes into the workforce without strong STEM skills? How much harder does it make their lives?

ANNE HAMPSHIRE: What we've seen over the last 10, 20 years is that there's been a fundamental shift in the types of roles that are available and, as Ian was saying, there are going to be a whole lot of new ones going forward. But what's happened over the last 20 years is that lots of very low skilled jobs have disappeared so the starting point for employment nowadays for young people is so much higher, the expectations of employers are so much higher. And so if young people come out of school, even if they've got Year 12, without those very strong mathematics skills then they're going to really struggle.

I had a conversation this morning with a CEO of an Australian very large international employer in the hospitality area and he said that maths skills are absolutely critical for his workforce. We weren't actually talking about STEM, but he just raised that himself. He said that in their business – and it's a very young profile in terms of their employees – it's absolutely essential if you want to get anywhere you've got to have very strong maths skills and if young people, particularly from disadvantaged backgrounds, don't have those skills then the pathway for them is very difficult. And, we'll come to I'm sure, it's much easier to develop maths skills earlier on than it is to start much later in life and development them. You can, but the foundations are laid much earlier on.

PETE GOSS: Pushing one further, what about students who leave school in Year 10 and may be struggling to engage with many parts of life, what does mathematics mean to them?

ANNE HAMPSHIRE: I think many Year 10 young people if supported can actually go into important roles, as Diane was just flagging, in terms of the trades, in terms of apprenticeships, but they can't do that unless they actually have the skills. So we really need to very much support young people right across the age range, but particularly in Year 10 and then Year 12, to actually have those core skills for employment but also more broadly. The examples that Ian used about science in taking medication and using iPhones are also very much maths activities as well. If we want to cook tonight we've got to have some basic maths skills. So for young people there's the participation in work, but there's also the participation in life generally.

PETE GOSS: So let's quickly touch on a couple of other areas. We've focused very heavily on mathematics, what about coding, should every Australian student learn to code nowadays? Who wants to take that one?

IAN CHUBB: Yes, most probably and the reason that I say it with that small qualification I think is that I say yes because I think it's happening in most other developed economies. My simple view is that Australia cannot afford to lose ground, we can't afford to let the gap between us and other economies get so big we'll never be able to fill it. They are moving in ways and we can learn from those ways, we don't have to reinvent the wheel all the time, and we see what's happening in the United States and the push in that particular federation from the Federal Government to increase STEM skills and coding in schools, the development of schools sometimes with industry to introduce students at an early age to coding, which I was told the other day is really computer programming at a basic level. I think we should be aware of that because it sounds much more difficult than it might be using the Americanism of coding. But through Europe, through the UK, all of these governments are beginning to take a position on that and say yes. Can we afford not to? I would argue we cannot afford not to.

DIANE SIEMON: There are very, very simple programs now which are programming programs and one that comes to mind is Scratch and three and four and five year olds are actually using Scratch to create computer environments, create things that could be done for them, perform little tasks. So I agree absolutely, it is something that's I think rather non-negotiable and there are very creative ways of doing that. At the highest level it's actually a form of propositional calculus and it is a logical way of actually recording data and building up a logical premise and establishing rules that come into force in terms of argumentation and communication more generally. So I think we do need to think outside the square and getting back to your geography question before, I think subjects like that which are richly multidisciplinary, richly so. They deal with population statistics and a vast range of data in terms of Earth sciences and what have you and politics, and I think it's a critical area to apply a lot of science and maths skills. I guess if I had my way I'd be suggesting that everyone does geography as much as everyone does maths, so whoever asked that question he's got my support.

But yes, I think we do need to think outside the square. I think one of the problem's is we've been locked into an 18th century curriculum structure which has got subjects that were defined back in the monasteries of England many, many years ago and I think we do need to think outside the square. Many of the more adventurous schools are doing that, they have things like robotics has been around for some time and I think we do need more interdisciplinary-type subjects that really do engage with industry and actually engage students working in industry alongside researchers and scientists doing real work, seeing how maths and science plays out. So I think we've got to get beyond thinking of schools within ivory walls and see them much more in relation to industry and needs further. And if I could, I'd like to come back to the engagement question but I'd better not hog the floor.

PETE GOSS: I'm sure we'll have time. So that's a quick overview of why we think we might want STEM skills for all Australians and we haven't touched on the other traditional subjects, maybe we'll come back to them. But it's then important to ask how are we doing today? Let's try and get some facts on the table, which students are being supported and which ones are being left behind? We'll continue with Diane, how are Australian students actually comparing to other countries in maths?

DIANE SIEMON: Well, there's a lot of international data on this with the 2011 TIMSS Report, the 2012 Report of PISA, the big Program of International Student Assessment. There's a very considerable

number of reports that the Australian Council Educational Research have been responsible for and I think it's fairly true to say, and most people would recognise that, in terms of those comparisons, Australian children or students are not doing as well as in other countries and I think Ian's right to draw our attention to what is happening in competing countries.

So it is definitely the case that I think we have an issue, but it's not a simple issue. It's not a simple issue of just more maths or more teachers or more whatever; it's quite a complex issue because it's to do with I think very many competing demands. We're a very free society, we're not a command economy, people can do what they want, there's very attractive options in non-STEM courses that are competing, and I don't think we're doing a good enough job early on to establish the knowledge and confidence. We're too busy trying to do old skills rather than think about problem solving and creativity and applying the knowledge that you do have. And so yes, I don't want to dwell on it, there's a lot of data out there, I don't think we can hold our heads up as high as we once did and we do need to do something about it.

PETE GOSS: We will get to what we need to do about it. For the audience, could you give an indication by the time our students turn age 15, which is when many of the international tests are done, roughly how do we compare? How many months or years behind are we compared to the best students?

DIANE SIEMON: Even that's a complicated question because that's in the PISA 2012 data, but it's complicated by what you're talking about. If you're talking about low level skills or skills of applying relative low level procedures we do fairly well. If you talk about applied problem solving then we do significantly worse than our OECD partners and we've dropped down the list, I think we're about 19th now, don't quote me, but we've come down the list quite considerably in the sort of knowledge exactly that we need for the future. No-one actually needs these sorts of basic skills anymore; we've got digital tools to do that. What we need is depth of understanding and knowledge and confidence to embrace different problems and different circumstances, and I think we need to do better.

PETE GOSS: Thank you. Ian, could you give us a quick snapshot overview of some of the other science areas?

IAN CHUBB: Well, I think it's exactly the same issue. I think science in the international testing hasn't gone backwards as fast as mathematics literacy, but we're falling behind other countries and I think that should alarm us. There are all sorts of explanations, it is a complicated issue, but when you look at the data what you find is that at the more complicated end of this testing that's where we do least well and I think we ought not to be willing to accept that. That means we have to do something about it otherwise the gap will get too big and we'll never fill it.

PETE GOSS: Lastly before we move on to what we should do about it, Anne, a question from the audience, what safeguards are in place to make sure kids from low socioeconomic backgrounds are not excluded from STEM futures?

ANNE HAMPSHIRE: Peter, thank you to the audience member. There is some work available but our data would suggest there's nowhere near enough. So in the study that we just talked about, the PISA study, there's actually a two-and-a-half year gap in Australian students from high SES compared to low SES. So clearly we're not doing well enough; your background in Australia matters significantly in

terms of how well you do. That starts very early on, it continues through NAPLAN and it's all the way up to age 15 and beyond. So whilst there are some programs, some schools doing really good work, some organisations like ours, The Smith Family, that are trying to focus particularly on disadvantaged young people, the data would suggest, as it suggests generally in this maths space, we need to do much more, particularly for disadvantaged young Australians.

PETE GOSS: And interestingly for a panel which has two women and one man, we haven't actually heard about the difference between men and women. Looking at some of the NAPLAN data, young girls do better in reading early on compared to boys and then that gap grows, but what happens in the mathematics area?

DIANE SIEMON: Well actually, according to PISA, there's not much difference in Australia, so we must be doing something right. In our own work we found no significant differences at any stage in the work we've been doing using rich tasks. Where others have found some differences in favour of males in the junior secondary years and we weren't finding that difference, we hypothesised that it might have been due to the fact that our rich tasks and problems require a little bit more reading and required a little bit more explanation and perhaps girls were a bit more prepared to do that than boys, but that's a bit of a long bow. But the actual large scale data, like the PISA data, is actually not finding a significant difference and that's a good thing.

PETE GOSS: It certainly is. An audience member commented it's easy to focus on what isn't working in STEM education and asked what are the examples of the best practice in STEM education in Australia? This is a big question, so to help structure the responses I'm going to break it into three stages of education. We're going to start from the very beginning, before kids even get to school, move on to school education, and then think about what happens in Year 11 and 12. So I'm going to start with Anne with preschool. Another audience member highlighted that parents are of course big influencers. We often hear how important it is for parents to read books to young kids, but your *Let's Count* program takes a different tack and focuses on building preschool numeracy, can you tell us about that program and the effect it's having?

ANNE HAMPSHIRE: Peter, as you mentioned I'm a former maths teacher and I cannot tell you how many times I would be at a parent-teacher night and a parent would come up and say, "I'm no good at maths and neither is my child" as if it was something in the genes or in the water in the house. That's a really important cultural thing that we need to address as a nation, so one of the things that The Smith Family has been doing over the last five to six years is developing a program called *Let's Count*. We know that if we can actually support parents to support their children's early numeracy then that can really set them up in a very good way. And this is not about parents sitting down and doing highbrow calculus or similar, it's actually about finding maths in the everyday. We're talking about three to five years old in highly disadvantaged families and building the confidence of parents to realise that they can actually support the numeracy development of their children.

So we've done a program over the last five to six years with great support from a number of philanthropic organisations, including the Origin Foundation, where we've supported early years educators to support parents to develop the children's maths capacity. How does that practically work? There's training for the early years educators so that they feel confident and skilled to talk with parents so that they, in turn, can build their children's numeracy. We've also provided games, we've provided tip sheets, we've provided books, a whole pack that goes home, and helped the early

learning centre to do a whole lot of maths activities, but all about maths in the everyday. Often teachers would say to us, "We had this window during the day where we did maths, now we do it and we realise we do it all the time". In the home environment, when you're cooking; when you're washing, washing is about matching socks, that's a mathematical activity for a three to five year old; when you're out in the garden. There are so many everyday opportunities that parents can engage with their children around maths and what's *Let's Count* has done has made that absolutely explicit for parents and for children.

Has it worked? Well, we've had a three year evaluation of this program, 8,000 children in 17 disadvantaged communities across the country including Collingwood in Victoria, Ballarat and Shepparton have been involved in the program, 4,500 parents, and it's very clear from the evaluation that we've done that children who did the program have much stronger maths skills across all of the areas that we would like them to have skills in but, very importantly, had much more positive attitudes and dispositions to maths than similar children who didn't have access to the program. The dispositions piece, I think which Diane was flagging, is incredibly important. Do I think maths is interesting, useful and fun? These three to five year olds would say yes, yes and yes, and what the program is doing is setting up highly disadvantaged children as they make the transition to school to be able to be ready to take on that maths challenge, hopefully for the longer term.

PETE GOSS: Fantastic. And talking to a primary school teacher at my children's school they said that actually one of the markers for is a student ready to thrive when they first join school is can they look at a hand like that and know that it means five, as opposed to having to count it. Diane, any comments on that?

DIANE SIEMON: You've just raised one of my very big ideas. A really valuable skill is the ability to recognise numbers without counting, referred to as subitising, and it is recognised now in early curriculum, but in fact we're having Year 8 students in our project work who are very much lower socioeconomic, very underprivileged, they're pre-additive, we've found there's up to an eight year range in maths ability in every grade level from Year 5 to Year 9. Currently working in some quite low socioeconomic schools, quite significantly challenged schools where they've got up to 55% of their population at Year 8 is still pre-additive. Now, what that means is many of them are still counting on their fingers, many of them don't recognise numbers without counting which is, I agree, an early years aspect. They are being locked out of anything beyond working with whole numbers, they certainly can't work with algebra or anything that you might be expected to be working with in the Year 8 curriculum. They try and of course they've got a right to be exposed to the curriculum at their year level, absolutely, and we would advocate strongly that that's done in mixed ability groups so that they can learn from others.

But yes, going back to being able to recognise numbers, what we're doing in those classrooms, and it's working, is we're actually having five to ten minutes each day of subitising activities where effectively cards with a number of dots are placed up in front of these students and they're expected to just look at it and say how many. It's a way of building knowledge and confidence about these very basic ingredients of understanding. And a lot of students are finding maths difficult simply because they are relying still on counting by fingers in Grades 5, 6, 7, 8, they believe that if they don't know their multiplication tables off by heart by a certain age that they're failures and, of course, we contribute to that by sending those messages out. We need strategies to solve mental computation

problems absolutely, but you're not going to get that by rote learning and far too many schools and people expect that and, of course, the effect of it is you turn people off maths. They come in with obviously positive attitudes in a lot of cases but very quickly, by the age of Year 4, we're starting to suggest that maths is about knowing something instantly and if you don't you're a failure.

So we're establishing some very poor expectations, but we can do things about it, and that's what you're going to ask.

PETE GOSS: What do you do about that?

DIANE SIEMON: Well, I think there are many programs, many excellent programs that involve diagnosing or working through interviews, working to identify exactly what students do know and what they're capable of. And it's not rocket science, if you start from there in a targeted teaching approach to intervene then you can make enormous inroads. I mean, we had a PhD student working on one of our projects working with very seriously at risk Grade 6 students. She worked with them over two terms about twice a week just focusing on really big ideas, like subitising, like place value, like multiplicative thinking, and they had plenty of time, if you like, to regress before the end of project testing and there was a whole term elapsed, and all of those students made enormous growths. In terms of our framework they were at Zone 1, they went up to Zones 4 and 5 out of an 8 level framework and were at age-appropriate levels. And not just being able to do things, they were knowledgeable and confident and prepared to share their knowledge with others. The teachers said they're different people.

Now, there are lots of programs like this that support what I call a targeted teaching or an intervention approach from the early years, Ann Gervasoni has been involved with that, and I think that we can't accept that it's alright for so many kids to fail in maths and yet I had a piece in the paper just last week too about the parents saying, "It's okay, I was no good at maths". We'd never say, "I was no good at reading" and yet it seems to be perfectly acceptable to say that. Now that is just endorsing that it's okay to fail at maths. So it's much bigger than schooling. We've got to change some pretty fundamental cultural attitudes about maths and realise that it is maths out there every day and everyone is using it all of the time. But there are some great success stories. We do know what the issue is, it's some of these big ideas, we do know what to do about it and I'm currently working on a project with support from the Chief Scientist's Office that's addressing that in these underprivileged secondary schools and it's making a difference.

So we do know; we just need to pull our resources together and get on with it.

PETE GOSS: Very good.

IAN CHUBB: Just a quick comment on that. We also need to scale it up. One of the things that we're not particularly good at in Australia, and I don't want to be negative about everything, we do some things very well, but one of the things we don't do well is scale. So we have a whole lot of good programs speckled around the country, but we don't learn from them and then scale them, so they remain isolated and have their biggest impact locally, and I think that we've got to change that attitude too. I think there is a lot we can learn from each other and there's a lot we can learn that is good and we can then build it.

I was going to comment to one of Diane's earlier comments that according to the Thames data from 2011, Australian students' liking for mathematics falls from 45% in Year 4 to 16% in Year 8. So what is it that we are doing that is letting that happen and are we sanguine about it, and if we are we shouldn't be? Some of the programs that Diane's outlined and others that I know of around the country are trying to do something about it, but if we want to see the national level shift we've got to operate on a national scale and we can't leave it to a good school with a good teacher dedicated sitting somewhere in a state, somewhere in the country working tirelessly to try to improve all this and then find that the effect is local and we still slip backwards.

PETE GOSS: And in terms of that engagement, I think the idea that some countries are doing stunningly well in mathematics in testing is true, but in South Korea, which is one of the highest scoring countries, if you then ask the students do they enjoy mathematics and do they feel confident in their own skills the answers are no and no. So what we're looking for is a degree of achievement, a degree of engagement and a degree of confidence.

IAN CHUBB: We know that we couldn't import the Korean education system into Australia or the Japanese, and we wouldn't want to, but what can we learn from what they do that we could introduce into Australia? And I think Diane's right, we don't have a command economy, we can't say you've got to do this and you have to do that and you have to do that or else. What we have to do is make it so compellingly interesting that everybody wants to do it and that's not what we're doing.

DIANE SIEMON: Can I just make a comment, I said I'd come back to engagement and why is it that we have this dreadful decline in engagement? It's come up recently, if only we could fix this thing engagement, if only we could turn on a tap and they're more engaged. To me that's a symptom. We've got to look at the cause and the cause is not succeeding. Nothing builds engagement like success and if students achieve success they will absolutely astronomically engage. We've seen this in lots of areas, but particularly where you get students suddenly, I mean these Year 8 classes who are very much at risk, being able to work at their level and succeed they come to school more often. That was one of the things the teachers noticed, attendance improved, they arrived at class on time with their books, they didn't necessarily jump up and leave at the end of the lesson. The teachers reported that they had far less discipline interactions and classroom management problems.

It's not rocket science. We need to ensure students have success and it's not just about some whizz-bang technological magic trickery that's going to suddenly inspire and engage everyone. That's not the recipe. We need to engage with teachers, we need to engage with school leaders and, can I say, fundamentally what we've found from our project in terms of making a difference, and that's a scale issue, is leadership, leadership, leadership. In schools where there is strong commitment by leadership to STEM futures where those leaders then support their maths and science staff to have perhaps some extra time, to get some extra pair of hands, to help them prepare interesting activities and materials, they're prepared to invest some time and resources in professional learning. That's what's needed. It's not just training more teachers. Yes, that's needed to, we need to support teachers, but it's much bigger, we need changes in cultural values; we need to get to the core of the essence which, in my mind, is success.

PETE GOSS: Very good. I think that's true not only for mathematics, but also for the other areas of STEM. Let's touch briefly on those. Do we have examples of things that work really well in primary and early secondary for science?

IAN CHUBB: Well, the Academy of Science has run some particular programs that have been designed to engage both students and teachers and to elevate the thinking about science in primary. I remember I launched one in a primary school in Canberra and this young lad in Year 5 had produced a sort of polyurethane model of the solar system. He was very proud of it and as he held it up in front of the whole school and me it fell apart and he was methodically putting it back together and I said to him, "Did you enjoy this primary connections?" He said, "Oh yes, I learnt a lot" and he paused and he said, "So did my teacher". And I thought first he could take over from Jerry Seinfeld, but secondly it did seem that what it does is it does integrate the learning both for the student and with the teachers and so they, as it were, learn together in different ways.

There are a number of those programs where scientists are in schools. I think the basic message is that science as its practiced is awesome, science as it's taught is something less than awesome and you get this turn off, and you get the turn off because people can't see the practical application, they can't see why they need to learn many of these things. And it doesn't matter, talking to a bunch of really very high achieving Year 12 students and they were complaining to me about having to learn the periodic table. I said, "We had to do that too, but there many fewer elements in the first 20 when I learnt it" and they immediately realised they were talking to somebody that they didn't want to continue talking to. But the point was that it was taught not why but just very methodically, as it were, out of the book and they were committed to it, they would do it and they would go on to study science, but it was because they were intrinsically interested as it were, not because the teachers or the teaching had brought them along in ways that they understood why it was going to be awesome when they got up to their elbows in it.

PETE GOSS: Very good. So it's not as though we need to invent a whole lot of new ways, we need to recognise that we have some great ways of teaching and engaging and that providing that success to students is one of the major ways that is going to keep them engaged and then scale it up.

I've got one more question that I'm going to touch on before I'll throw it open to the audience, so start getting your questions ready if you would, and that is what should we be doing in Year 11 and 12? Should all students be required to study mathematics and/or a science up to Year 12? Should we still have the traditional disciplines or, as an audience member has suggested, maybe integrate all of the science disciplines into one that looks much more at systems thinking and the way that they're integrated?

DIANE SIEMON: I actually think there's a lot of merit in that. I think that if you're engaging Year 11 and Year 12 students in, for instance, modelling real world problems and you were collecting data, modelling that, making predictions, testing them out, it's multidiscipline but you're engaging in the very act of inquiry. And it seems to me that I think we've gone down those narrow discipline avenues for too long and we do need – I think we'll actually get better gains, you know, we'd get more physicists, we'd get more chemists if it was taught through the rich lens of reality and actually solving problems and, of course, you need mathematics for that as well. And it's not the mathematics of narrow schools though, it's the mathematics of modelling and it's the mathematics that uses digital technologies to represent very complex multidimensional situations.

So I think we do need to think about that. I think the problem with curriculum discussions is that they're camels built by committees and I guess they always will have to be and they're derived from long-standing social histories and traditions about what curriculums should look like. And it's very hard

to make a quantum jump from what exists to what needs to be, but I would very much welcome some national level thinking about the nature of curriculum. Not worrying about creating the curriculum there and then, but thinking about at a much bigger level what sort of curriculum do we need and how might it be phrased and what sort of teaching workforce and/or resources and what sort of relationships with industry do we need to support that? We're not adventurous enough. We're just simply too 18th century.

IAN CHUBB: I would agree with all that. I think it's very true that we're not adventurous. Putting it less generously, I think we've become very risk averse and some of the issues that we will confront in the future, all of these complex issues, whether it be something like climate change or pandemics, all of those sorts of issues will require people working outside single discipline boundaries to solve or to manage or to mitigate. And so I agree, I think we should be doing it like that much more than we do. My caution is only that we can't afford to lose the strength of the discipline. I've seen in too many universities over my life where interdisciplinarity is in fact an excuse for diminishing somewhat the importance of the physics or the mathematics or whatever it might because it's mixed in with other things and it all sort of bubbles to the surface.

I think we have to be very careful to encourage interdisciplinarity, multidisciplinarity, but we've got to be careful to build off strong disciplines otherwise any gains are lost.

PETE GOSS: Thank you. Anne, do you have any views on whether we should require all students to student this through to Year 12?

ANNE HAMPSHIRE: I think if we think about both the employment world that young people are now facing and also the broader reason that we have education, so to prepare them to be citizens of the 21st century, I think there's a fairly compelling case that we have a lot more young people doing mathematics, doing science and being able to really live in what is now a very different world than it was back in the 18th let alone 19th or the 20th, yes.

PETE GOSS: And that would imply some trade-offs. Rather than getting into that, you've been very patient, thank you, I hope you've found the conversation interesting so far but now it's your turn to guide it. We've got about 15 minutes for questions, there are always more questions at the end so please get on early and I will call on as many as I can.

AUDIENCE: A lot of what the panel has talked about so far has been teaching STEM skills in primary and secondary school. I was just wondering your thoughts on teaching them to older young Australians, so young Australians between the ages of say 21 to 40 who are passed the education system. Do they need to be reskilled? Do they need to be looking at developing mathematics skills or are they a bit of a lost cause?

PETE GOSS: Great question.

DIANE SIEMON: I couldn't agree more. We have talked a lot about schools and teachers and principals, but that's only one aspect of the whole educational pie. There are many, many stakeholders involved in this and I think we need to be much more creative about involving business and education and community education and we need multiple re-entry points. We need to understand where people are at and we need to have age-appropriate ways of teaching them so that

they can retrain. At the moment those students that are leaving at 15 that Anne is talking about, they don't have the knowledge, confidence and skills but you'll have to teach them in age-appropriate ways through diploma courses and TAFE. And then that's another issue about the constraints of that system in terms of it's very highly structured and that doesn't necessarily suit these sorts of learners.

So I do think we need a bit of a national strategy and we need a multidimensional approach that not only talks about schools as part of the education, we think about training. Business does a large amount of training, in-house training and it's a terrific source of retraining opportunities. So does the adult education sector and what have you, but also I think there are multiple opportunities through agencies in community sectors, for refugee centres for instance offering re-entry programs. So I think it's crucial.

AUDIENCE: In the OECD study that was mentioned previously, PISA, they surveyed principals about teacher shortages. In that Australia had some of the highest shortages in the world in science and maths teaching and probably, most alarmingly, out of the 61 countries that were surveyed we had the second-highest concentration of those shortages occurring in disadvantaged schools. So what can be done to encourage teachers into schools to teach science and maths, particularly our most disadvantaged ones?

IAN CHUBB: It's a big problem and it's been a problem for a long time. There have been lots of attempts to change it and very few have been successful for the long term. So, again, I think it means that we have to sit back, think through what the implications are and then how do you do it, what can you do. I don't know that we had the same sorts of problems when, for example, going a long way back now when many teachers went to university on teaching bursaries and cycled through the school system. Now there would be some people, probably some people up here, who would think that was not a good time. I think it was one of the ways in which we got well-qualified teachers into schools across the country and they didn't all stay teaching but some did, but even those that didn't contributed skills for a period in rural and remote areas, for example. It seemed to me that whilst you wouldn't just go back to the past and say we've got to do that again, you can learn from that and you can say are there ways in which we can provide incentives to get really well-qualified teachers into schools where they presently don't exist?

We did a study in 2010 on the distribution of qualification of teachers going from metro through to regional and ultimately remote and it's absolutely clear what you would expect, and that is that the further away you go from the big city the less qualified are the teachers who are out there teaching subjects. I mean, they might have their degree or diploma, but they haven't got a specialism in maths or a major in maths or physics or chemistry, whatever it might be. So there are things that we have to do, but I think in part it's recognising that we have an issue and a problem. One of the things that disturbs me about NAPLAN is that there's a two year performance gap between our best performing jurisdiction and our worst performing jurisdiction. Now, we know that so what are we going to do about that? How do you recognise these questions, recognise that there's an issue and then work out how to do something about it? And it does mean, I think, thinking through how you deploy your teaching workforce, how you make sure, I mean, I saw a story the other day that there are 40,000 underemployed teachers in New South Wales. It seems a huge figure, but that was the figure that was quoted. If that's true why aren't we doing something about using those talents and skills

differently or better? How do we provide incentives? How do we do things that make it worthwhile and worth their while too?

So it's a big and complicated issue, but it's one that, first, we recognise there's a problem and then resolve to do something about it, and clever people will find a way to do it, rather than pretend it's not happening because we don't look at the data.

DIANE SIEMON: There's another compounding issue here too in that the research on whether or not more mathematics makes a better maths teacher is actually equivocal. On the positive side, we do have a range of tools to help teachers and in my experience where perhaps teachers are teaching out of field they may be a very good biology teacher, for instance, but take on a maths class. With appropriate support those very good teachers in their own domains can become very good and effective mathematics teachers. So it's not a hard and fast rule. A history teacher that is really fascinated by the idea of historiography where you collect and analyse data and interpretations and things can also come to maths with support. So I think we are not going to fix this overnight, we simply do not have the resources to do it. I think we have to embrace what we have and think through what tools and resources are needed, and that is a resource but it's a less cost, and we need to be thinking about how to support those people.

Even the sort of work I'm talking about where we're having to take students right back to where they're comfortable and know, a really highly trained secondary maths teacher isn't obviously very confident with what might well be primary mathematics concepts. I'm one of the people that went through university and I'm still teaching, but the thing is I did university mathematics, loved mathematics and came across Year 7 students who I couldn't possibly understand what their problems were. I mean, it motivated the next 40 years of my life to be looking at where those problems have emerged from and what we can do about it. So I'm actually a little bit optimistic. Seeing some of the outer school teachers we're working with equipped with professional development and tools, diagnostic tools, advice about how to go about responding to the learning needs, are actually doing a really good job. So I think we have to just embrace what we've got and work with the resources better.

AUDIENCE: Aside from the obvious retraining once somebody is actually in a large company, where else can large companies, from your perspective, make the most difference in promoting STEM fields to younger years?

PETE GOSS: Good question, we're working on this one.

IAN CHUBB: I'll start somewhere different and try to get back to your answer. We sponsored a project from my office where we sent maths teachers into businesses to see how maths that they thought they were teaching was actually used and it came as a big surprise basically. They found that it was applied differently, used differently, of course the concepts and so on, but it was used differently. So one of the things that I've been arguing for quite some time now that we actually have to break down the barriers that exist between schools, universities and the business world in quite different ways from the ways that we've thought about doing it before. I talk to a lot of business people in this job, they're anxious that something be done but they don't feel that they have too much influence on the way the universities or the schools or the vocational colleges actually engage with them. So they're

not interested in tokenism, they're not interested in a free dinner twice a year and then they go away and somebody can tick a box and say we have a visiting committee that has visited and advised.

So I think, again, when you look at what's happening in the rest of the world the engagement between the business community and education providers is at least one order of magnitude more significant than it is here and they've worked out ways to do it. They've done it in Europe, they've done it in the US, they're doing it in Canada, and we are still operating largely with some stellar examples of the opposite, but largely as we've always done. So it's a cultural issue, it's a recognition issue, it's a recognition that most of the people that go through our hands as education providers will end up employed somewhere and it's not unreasonable to ask employers what they would expect to be able to see in the people that come through the education system.

Now, some of them I think are silly, they expect them to know when they finish what button to press on the machine the day they walk into the business. One employer said to me that graduates these days were useless in their business for at least four years. I thought that was silly and I said so because I think today's graduates know a lot more than my cohort did when they finished. So it's a question of how you use that and how you integrate that into what the options are that are available for the student. I think universities have tended to narrow the focus a little too much. There has long been a presumption that we're teaching for the next Honours year and the next PhD cohort. I think that's probably true generally speaking, there are some good examples of the opposite, and universities have to change the way they think they are preparing people for the destination that is the inevitable destination for most.

And business has got to be involved in discussing that and finding ways to make sure that that preparation is appropriate, without it being so specific if they don't work for that company in that office in that room with that button to press they can't get a job. It's got to be opening opportunities, rather than closing them off and business needs to be involved.

ANNE HAMPSHIRE: One of the things that The Smith Family does a lot of is actually create relationships and partnerships with industry. So we have partnerships with many, many, many hundreds of corporates across the country because we know that's a critical piece for helping our young people to feel engaged in the world of work. So many of the hundreds of thousands of young people that we support across the country engage in a corporate world around what are the opportunities here, what are the jobs here and that then gives our young people a real sense of what might be possible. A bit like you were saying Ian, teachers don't understand, young people in particular don't understand what might be possible, but it's through acting as a broker for these corporates, bringing the young people into the workforce and giving them a work experience, a work inspiration example of what is possible really does fundamentally change, from our experience, what a young person thinks might be possible in the employment sense.

So I think having much more closer partnerships yes, with education systems, but also sometimes it's actually easier if the not-for-profit can provide that facilitation for the school and the young person.

DIANE SIEMON: There's some very interesting research on this, I think it's around Year 8 or 9 they've found that what students believe at that time to be where they'll end up is actually the best predictor of where they end up. So if we can intervene at that point to give them images of themselves in worlds that they perhaps can't imagine because they're coming from lower socioeconomic or different

cultural backgrounds that don't anticipate involvement in those sorts of industries, I think that would be fantastic. That perception is probably going down younger and younger with social media, so I don't think we can leave it to Year 11, 12 and 10 when you have all the careers teachers' advice under the world. I think we need to be looking at perceptions earlier and, for instance, we very happily take Year 9 students away for a whole term to some outdoor education pursuit. Why not take some Year 8 students into industry – obviously not for a whole term – working with people on problems, not just empting the office trays, but actually engaging in the thinking processes around a particular problem and just even what the nature of stringing up wires and maintaining wires in a network or planning on where ambulances should exist or where fire brigades.

There are all sorts of things that students can engage with and understand. They may not be able to solve the problem, but they can engage with it, see usefulness in it and perhaps imagine themselves contributing to those solutions down the track. So industry I think has a big role to play to build the imagination, because unfortunately their imaginations are too strongly determined by their social media friends and that's actually having a confining and narrowing concentrating effect and it's denying them possibilities to think outside the square.

PETE GOSS: There are also some fabulous programs, there's one in rural Victoria in a dairy industry where the local dairy company is working very closely with the school to align the curriculum and help the students see where they might transition, that both provide a source of employment, but also a path forward for the students. So there are some of these things happening.

AUDIENCE: We haven't spoken a lot about teacher training in elementary schools here and there's a lot of evidence that teachers graduating from teacher training programs are not prepared in the maths and science that they're going to be teaching to kids. I was wondering what the role of universities that trains teachers is in fixing this problem and how that will change under a demand-driven system where there are more people going into teaching?

DIANE SIEMON: Guess that's my domain, given that that's what I do. I think we do on the whole train teachers fairly well to teach the mathematics that they have to teach. Having said that, we tend to be attracting a cohort into primary teacher training who have had fairly negative experiences of maths for 13 years. They've done maths, they've remained resilient and done some form of mathematics, but we have a large job in four years of undoing some preconceptions and building deep understanding and problem solving and going beyond what they perceive to be mathematics. So I think on the whole we do a reasonable job given the time we've got. Most universities now will have students doing maths every single year of their training with electives on top of that.

So we're trying to do the best we can. The Teacher Education Ministerial Advisory Group, the recent report is advocating that there'll be end of graduation testing in literacy and numeracy. We've no idea that that will look like and whether or not testing is the way to go, but obviously it's feeding the perception that they're not good enough. But certainly people do have different strengths and abilities and, as I said, we could always be doing more but, to some extent, we're limited by the people that are electing to do primary teaching.

IAN CHUBB: I would say that it might be so for maths but I'm not sure that it is for physics and chemistry or biology. As a Vice-Chancellor or a Deputy Vice-Chancellor in three universities that had an education school and a science school, I know how hard it was to get them to talk to each other in

any way other than when I was in the room. And the previous government and this present government had put money up to try to design some education programs pre-service which would mean that the scientists teach the science and the educators broaden the pedagogy. I think the problem, as I've observed it over 20-odd years now, is that it is not often enough that the scientists are teaching the science in pre-service education programs, so they're not actually taught by people who are scientists pushing back science and understanding knowledge, research, whatever. They are more often taught by people who are themselves or were themselves in the school system and personally I don't think that's good enough.

I think if we're going to have teachers come out understanding science, physics, chemistry, whatever, knowing how it's used, how it's applied and what it's used for, how awesome it can be, then they need to be taught by people who think it's awesome and that will very largely be people who are doing it. So I think we've got work to do on it, I think it will be interesting to see how these designed programs come out, where for a university to get the money there has to be a sign off saying that the science school and the education school have combined to develop this program particularly. It will be small scale. If it works we've got to find a way to scale it up and that will be the next challenge.

PETE GOSS: You have very generously given of your time. Part of our compact with you is that we will get you out of here as promised on time, so I'm afraid there's only time for one more question.

AUDIENCE: Peter, it's not a question, it's three observations. The first is I think we've been treated to a terrific, a really terrific panel discussion tonight and I'd like to thank Anne and Diane and Ian and you for that. People can clap you at the end, but I would say that. The second thing is, and Ian has raised it tangentially, I've spent 50 years as a scientist. He sent me PhD students when he went over to the dark side into administration and they came from Flinders to Monash and one of the things that's driven me as a scientist is the feeling of wonder. And if I wanted to inculcate a feeling of wonder into kids not three to five, like Anne's, but in early secondary school, I would start each week showing them David Attenborough. And you talked about geography covering a lot of fields, that'll do everything and if you can get the kids wondering at that you're making inroads into it's not nerdy, it's wonderful.

And the third thing I'd like to say, Anne used almost interchangeable engagement and commitment and I remind her that there is a difference best exemplified in the English breakfast of bacon and eggs, a process in which the hen is engaged but to which the pig is committed.

PETE GOSS: So at that point we will wrap up, thank you. Thank you very much for your time, thank you to our panellists, to Professor Ian Chubb, to Professor Diane Siemon, and to Anne Hampshire. Thank you very much to the State Library, I would remind you that the Australian Learning Lecture is going to be on on Thursday, it promises to be terrific, that will take another look joy and data, we would all be believers that you need to have both joy and data. But thank you very much for coming along and I hope you enjoyed the evening.

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