APPENDIX 3: REPORTS FROM THE OVERSEAS VISITS

GATSBY

1. INTRODUCTION

This appendix contains the full reports from each of the six country visits.

We carried out a preliminary survey of 11 countries, described in Appendix 2. From it, we selected six countries[i] for the overseas visits. We selected countries that we knew from international comparisons such as PISA and TIMSS to be successful in science education, and where our preliminary survey had identified an expert witness who would be well placed to help us organise and inform our visits. These expert witnesses were both knowledgeable about science education in their country, and independent enough to give an objective view. Typically, they were university academics specialising in science education: their names are in the individual country reports.

The six countries we selected to visit are listed below. Detailed reports from each visit follow in this appendix.

Australia (Victoria), chosen for its success in science education and its cultural similarity to the UK. We visited four secondary schools in the greater Melbourne area (one being independent, the others state-funded) and two science centres.

Finland, chosen because of its consistently successful science education and the similarity of its comprehensive system to the comprehensive norm in the UK. We visited three schools in the Helsinki region and met teachers and officials at the Finnish National Board of Education.

Germany, chosen for its success in science education. We visited three academic secondary schools (gymnasia) in the Hamburg and Kiel region and met teachers and science education researchers.

The Netherlands, chosen for its successful science education and its cultural similarity to the UK. We visited three general academic schools (VWO and HAVO[ii]) in Amsterdam and Utrecht and had a workshop with teacher trainers in Amsterdam.

Singapore, chosen for its consistently successful science education and its historic links with the UK education system. We visited three secondary schools across Singapore and met with officials and master teachers at the Academy of Singapore Teachers and with science education academics at the National Institute of Education.

The USA (Massachusetts). Massachusetts is the highest-performing US state in PISA. We visited three high schools in the Boston area and met officials in the Massachusetts Department of Education and the Boston Public School District.

Altogether, we visited a total of 19 schools across six countries. At each school we observed lessons, toured the science facilities and talked with students, science teachers, science department leaders and school leaders.

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[i] In some cases, we selected specific states within a country, such as Massachusetts in the USA, and Victoria in Australia, on the basis of the known international performance of those states.

[ii] In the Netherlands, VWO schools are pre-University, and HAVO schools are generalacademic.

APPENDIX 3: COUNTRY REPORT: AUSTRALIA (VICTORIA)

GATSBY

1 EVIDENCE GATHERING

This report has been written by John Holman and Beth Jones and is based on the following sources. Further details of the sources are in Annex 1.

A. Desk research.

B. Visits to schools in Melbourne: Roxburgh College (public school, years 7–12) on 7 March 2016; Penleigh and Essendon Grammar School (PEGS, independent school, K to year 12) on 8 March; Blackburn School (public school, years 7–12) on 8 March; and Melbourne Girls' College (public school, years 7-12).

C. Visits to two science centres: Quantum Victoria on 7 March and Gene Technology Access Centre (GTAC) 7 March 2016.

D. A meeting with Professors Russell Tytler of Deakin University and Vaughan Prain of La Trobe University on 9 March 2016.

E. A visit to Museum Victoria on 8 March 2016.

The visits and meetings in Melbourne were organised by Dr Graeme Oliver of La Trobe University, Melbourne. He also provided individual expert advice throughout the visit.

2 OUTLINE OF EDUCATION IN VICTORIA, AUSTRALIA

This is a summary: there is further detail in Annex 2.

Australia is a federal country with eight states or territories, of which Victoria is the second largest, with a population of 5.55 million out of a total of 23.5 million.[1] Like most of Australia, the population is concentrated in coastal cities: in the case of Victoria, by far the largest is Melbourne, population 4.09 million. Outside the cities the population density is very low.

States are largely autonomous in education policy, and until 2010 there was no federal national curriculum. Victoria has its own independent policies for curriculum, assessment, teacher employment and school organisation. There is a relatively high proportion of independent, fee-paying schools in the state, attended by 25% of students. Independent schools have a small federal contribution to running costs: at PEGS this is 26%, but it varies according to need in the area.

The school year usually starts in late January or early February and runs until mid-December, with a short holiday between terms and a long summer holiday in December and January.

Victorian education is successful by Australian standards – it is the highest achieving state after the Capital Territory (which is very small). Australia as a whole does well in international educational comparisons: it was ranked 10th (out of 37) in the 2012 PISA science tests.

The state-funded secondary education system is broadly comprehensive. There is a high degree of parental choice: around 96% of Australian students attend a school that competes for enrolments with at least one other school. Most secondary schools are year 7 (age 12) to year 12 (age 18). Compulsory schooling lasts until age 17 but over 84% of Australian students stay on to year 12. Both general and vocational programmes are offered in upper secondary schools. Students completing an academic pathway are awarded a Victorian Certificate of Education (VCE), and those on a vocational pathway during years 11 and 12 are awarded the Victoria Certificate of Applied Learning (VCAL). Scores in the VCE are used to compile the Australian Tertiary Admission Rank (ATAR), which is used to decide which universities the student can get into. The ATAR algorithm includes a weighting for perceived subject difficulty.

Of the 55,500 students that completed year 12 in Victoria in 2015, 53.2% of them enrolled onto a bachelor's degree. Students normally attend a university near their city, leading to a close relationship between schools and a small number of local universities. Australian universities are highly rated by international standards. As in England, Vocational Education and Training (VET) has a lesser reputation, and there are multiple initiatives to improve VET to meet the demands of the labour market.

[1] www.data.oecd.org/australia.htm

2.1 ACCOUNTABILITY

Victorian schools operate under an accountability regime that is much lighter-touch than England's. School performance data is available from the Myschool web portal, a comprehensive and easily used system giving comparative data (on test results, attendance, finances etc) for all schools in Australia.

There is no inspectorate. School principals are held to account by senior instructional leaders from the Victorian Regulation and Qualifications Authority (VRQA), who draw on the results of the school's self-audit. There are standardised parents' and students' surveys which schools are required to carry out each year, the results of which are published. In some schools, students are also asked to reflect on the pedagogy of teachers.

3 SCIENCE EDUCATION IN VICTORIA

3.1 SCIENCE IN THE SCHOOL CURRICULUM

Curriculum

The basic requirements are laid down by AusVELS (Australian Curriculum through the Victorian Essential Learning Standards): this is Victoria's interpretation of the Australian national curriculum, which applies up to year 10. However, curriculum documents allow wide scope for interpretation, and schools in Victoria have much autonomy in the way they interpret them. So there is wide variability among the curricula followed by different schools.

In secondary school, students generally take a common course in science in years 7, 8 and 9, taught as general science. In year 10, there are elective options usually based on the declared science subjects of biology, chemistry, environmental science and physics. In Penleigh and Essendon Grammar School, the newly-introduced year 10 science scheme consists of a series of five integrated thematic modules, of which students must chose a minimum of two. In other schools, the organisation of year 10 science is more traditional.

In years 11 and 12, students choose among the subject units offered by the Victorian Certificate of Education (VCE), which includes 90 study or subject units, 30 of which are vocational. Schools decide which options they will offer. To graduate the VCE, students must satisfactorily complete a minimum of 16 units: of these, 13 can be from VET. Most students graduate with more than the minimum number of units. Teaching in years 11 and 12 follows the VCE syllabus quite closely.

About 60% of students take at least one science subject at VCE. The most popular science subjects are psychology (sic) – taken by 35% of girls and 15% of boys, biology – taken by 30% of girls and 15% of boys, chemistry – taken by 20% of girls and 20% of boys, physics – taken by 20% of boys and 10% of girls. It is not possible to provide figures on students doing multiple science subjects and the combinations of subjects they are taking.. However, there are concerns about low rates of progression to science in VCE: Australia has one of the lowest rates in the OECD of progression to post-compulsory science.[2] Like many other countries, we heard that uptake into physical sciences and maths was significantly gendered.

The Victoria Certificate of Applied Learning (VCAL) is a vocational alternative to VCE in years 11 and 12. It includes practical work-related experience, as well as literacy and numeracy skills. In Roxburgh College, for example, about half of students follow the VCAL route, but in Melbourne Girls' College no students do.

Assessment

Below year 11, the only external assessments are in numeracy and literacy (maths and English). Students take the National Assessment Program Literacy and Numeracy (NAPLAN) assessments in years 3, 5, 7 and 9.

Beyond these, all school assessments in years 7 to 10 (including those in science) are set and marked by teachers, including regular portfolio assessment tasks and end of year school exams.

The VCE is largely externally assessed and, because of its critical role in determining university entrance, it plays a powerful part in shaping what goes on in years 11 and 12. 60% of a science VCE Stage 2 grade is based on a written exam, 40% is internally assessed. The nature of the internally assessed component varies between science subjects: in physics, for example, it comprises a combination of school-based tests, an essay and an

[2] www.audit.vic.gov.au/publications/20120606-Science-and-Maths/20120606-Science-and-Maths.pdf and www.eprints.qut.edu.au/73153/1/Continuing_decline_of_science_proof.pdf

extended practical investigation of 8–16 hours. The assessment system is currently in a process of reform, with the new VCE 'study designs' (specifications) being introduced in January 2016. During our visit, students in year 11 were studying the new qualifications and year 12 were the final year to be studying the old system. The weighting of internally and externally assessed components remains the same, but the sciences now all have a larger investigative component. Part of their second year of study will involve undertaking an investigation and presenting it in a poster format. Students will also be required to keep a log book of all their practical work, which can be used as an assessment tool by teachers if they choose to. Assessment of the first year of study (units 1+ 2) relies solely on a school's judgement and does not get reported to the VCAA. It is the second year (units 3+4) that determines the students' final score. Teachers are given advice within the VCE study design about ways in which they can assess students through the course. They are free to choose their approach but must vary it throughout the course. Assessment approaches include annotated log books, media analysis and reports on investigations.

The introduction of an extended investigation across all three sciences, and its more prominent position in the VCE, was in response to pressure from universities for a greater proportion of extended investigations.

Schools have considerable autonomy in deciding how to carry out these internal assessments for the VCE, provided they are within the required criteria. At Stage 2 teachers' internal assessment marks are moderated statistically against the mark in the examination.

Science teachers

Secondary teachers are licensed to teach a particular subject specialism at VCE level and are not supposed to teach outside it. Principals, however, have considerable discretion in making teaching appointments, and there is no formal monitoring of the adherence to the specialism requirement. The licence to teach is issued by the state in which the teacher works (in this case, The Victorian Institute of Teaching). Most secondary teachers have a degree-level qualification together with a Masters level postgraduate teaching certificate, which nominally takes two years of study but can be achieved in a single year by treating teaching practice as part of the first year of teaching. (No longer so.) A teacher's practical skills are not focused on within their training route; they are expected to develop them 'on the job'.

According to the OECD, teachers in Australia have a higher than average proportion of contact time, and consequently less time available for lesson preparation and professional development. We were told that there are few incentives to take part in continuing professional development (CPD), though there is an expectation, audited by the Victorian Institute of Teaching, that teachers do 100 hours of CPD over a 5-year period in order to remain registered. Most of the CPD we heard about was generic rather than subject specific, though the Science Teachers' Association of Victoria (STAV) runs a programme of science-specific CPD. STAV also has a technician arm; LabTech. We were told that there is not a lot of CPD specifically related to practical science: 'We mainly rely on our colleagues'.

Schools also support their teachers to learn from one another. In several schools we visited, schools had initiated learning communities, in which key areas were focused upon within small teams of teachers from different disciplines.

3.3 SCIENCE BEYOND THE CURRICULUM

The network of science centres was established in Victoria in 2012, following an initiative by Victorian Government to provide opportunities for students to experience cutting edge scientific research and developments. We visited two centres in Melbourne: Quantum Victoria, specialising in the physical sciences, and the Gene Technology Access Centre (GTAC). There are six centres spread across Victoria, each specialising in a different aspect of science or technology. The centres have performance criteria requiring them to engage with all schools in Victoria, with particular emphasis on inaccessible rural schools and on socioeconomic deprivation. They have an interesting model for reaching remote rural schools, involving a combination of ICT, video links and outreach visits. There is an interesting model for managing practical work through video link. GTAC run a particularly interesting programme, which trains and pays PhD students to run practical sessions with students. Session are supervised by a member of staff who is trained as a teacher, and paid in line with school teachers.

The science centres are very well equipped with laboratories and equipment, and there is a strong emphasis on practical activity. At GTAC, we were told there is a lot of interest in using the centre's facilities for VCE assessed investigations. The centres also provide CPD for the teachers accompanying their classes.

Museums Victoria is a federation of interlocking museums including the Melbourne Museum and Science Works, both of which have extensive science collections. The museums have 17 million specimens, three-quarters of which are science-related. They are seen to be an integral part of the Victorian education system. The Museums use the science centres for outreach as well as having extensive on-site programmes. 59% of schools in Victoria come to the museums: there are nearly 300,000 student visits a year. Many of the on-site activities involve practical science.

One of their most successful exhibitions to engage teenage students is their 'Top Design' event.[3] This exhibition displays the best project work produced by VCE design students as part of the VCE 'Season of Excellence'. Final products are displayed alongside portfolios of work and a season of talks runs alongside the show. They are currently exploring whether it would be possible to use a similar model to showcase excellence within the new VCE science investigations.

There are opportunities for schools to visit university laboratories to see and use modern equipment such as spectrometers. Given that most Victorian schools are in the greater Melbourne area, such opportunities are within reach of the majority of schools, but teachers felt they did not make the most of them.

4 RELEVANT FINDINGS

The schools we visited were well-ordered and purposeful, with enthusiastic, motivated teachers. Students were co-operative and well behaved. Teachers appear to be genuinely motivated by the value of teaching rather than in response to any accountability system.

4.1 TYPES OF PRACTICAL SCIENCE

The types of practical science we saw were similar to England: a mixture of short experiments designed to confirm theory, and longer more investigatory experiments. In years 11 and 12, a significant amount of time is spent on practical assessments.

Science teaching and practical work are approached with appreciation for the range of cultures and experiences of the students. In PEGS we saw a lesson in which Aboriginal Dreamtime stories were used to introduce astronomy.

4.2 HOW FREQUENTLY?

As always, it is difficult to gauge how frequently practical work is done. The average seems to be about once a week at all levels – similar to, but perhaps a little less frequent than, England. Lessons were often approximately 70 minutes in length.

4.3 ATTITUDES TO PRACTICAL SCIENCE

Practical science is unquestioned as a core part of science teaching. Teachers told us that practical work:

- is motivating and enjoyed by students
- consolidates learning
- gives students skills that will be valuable later, for example at university
- helps give a sense of being a 'real scientist'.

[3] www.museumvictoria.com.au/melbournemuseum/discoverycentre/top-designs

Teachers felt that authentic hands-on experiences are essential to stimulate curiosity. Unexpected outcomes are an important part of that authenticity. The cognitive dissonance between what is expected and what actually happens helps to strengthen conceptual change. The importance of the unexpected was reinforced by several of the students we spoke to: one told us how they had distilled cola to get pure water: "But the interesting thing was the gunk that was left behind". Another told us about mixing lead nitrate and potassium iodide solutions: "I knew it would turn yellow, but I didn't expect the weird streaks".

In the strongly multilingual Roxburgh College, we were told that for students with poor English, practical work is a valuable way to reinforce learning through concrete experiences. Teachers felt that their own practical skills enabled them to model correct techniques and enhanced their professional status. Their autonomy also allowed them to explore different approaches to practical work: one teacher explained how they made use of the school's teaching kitchens during chemistry lessons.

The influence of assessment pressure is not felt until the end of the VCE. We heard that some students may ask: "Why are we doing this experiment when we could be practising exam questions?", but that this is mainly confined to year 12 if it happens at all.

Teachers emphasised the importance of discussing practical work results, preferably in the same lesson in which the experiment is carried out.

4.4 FACILITIES AND FUNDING

The laboratories we saw were mostly well designed, with flexible facilities that allow both theory and practical work. Typically, labs have fixed benches projecting outwards from the wall, provided with services, and moveable furniture in the middle. Similarly to England, class sizes are up to 25, and students work in groups of two or three. The number of labs for a given size of school was similar to England. Most of the labs were modern and well maintained. In the independent PEGS, we were told that high quality labs are an important way to attract parents.

Typically, we were told that funding for equipment was adequate and that funding never presented a barrier to practical science. In schools such as Roxburgh and Blackburn, with rapidly growing numbers of students, laboratories can be stretched. Funding is based on predicted numbers of students over a 5-year period, so rapidly changing communities can sometimes be underserved. The process of buying equipment was also similar to the UK: technicians would often be tasked with looking through catalogues of equipment to find the best deals. We were told that is was deemed too bureaucratic to set up a centralised system.

Text books were used regularly by teachers, with students often having their own set of science text books. PEGS had moved towards e-text books, which allowed content to be updated and for teachers to pick and choose where they wanted to direct students.

At Roxburgh and Melbourne Girls College, we heard plans to create STE(A)M spaces within the schools that would allow more open ended, student led projects. This would be a space to explore 3D printing, coding or invention.

Schools' provision for ICT seems similar to schools in England, and most students have their own iPads or portable computers. However, although we saw one excellent lesson involving gas sensors, we did not see or hear about extensive use of ICT in lessons. We were told: "We do not use it as much as we should". Limiting factors appear to be time, availability of working equipment (especially data loggers) and teachers' know-how.

4.5 TECHNICAL SUPPORT

All the schools we visited employed technicians to support practical science, with well-stocked prep rooms. However, the number of technicians in a given size of school was significantly lower than in England. In Roxburgh (1347 students) there were 1.3 full-time-equivalent (fte) technicians, supporting an estimated 10–15 practical classes per day; in Blackburn School (1100 students) there were 1.4 fte; at Melbourne Girls' College (1300 students) 1.0 fte; at the independently funded PEGS (2400 students) there were 3 fte. We did however hear that there was a relatively high turnover of technicians, as many were skilled graduates but the salary would never rise above that of a beginner teacher.

In the schools we visited, a significantly smaller number of technicians appeared to be supporting a similar, or only slightly lower, level of practical activity to England's. What might be the explanation for this? It could be that Australian technicians are more productive: those we met were certainly well qualified and highly motivated. Another explanation could be that teachers do a more limited range of practical work, enabling technicians to work more efficiently. We also heard from teachers in Roxburgh that they share out the preparation of practicals to save time. Several teachers will carry out the same practical in a week, and one teacher will take the responsibility for ordering and checking the equipment. One technician told us: "To get everything done, you need to have your teachers in line".

4.6 PROJECT WORK

We saw few examples of extended science projects. Assessment for the VCE allows scope for students to carry out investigations, but we got the impression that these are often formulaic and designed to optimise performance in assessment. Nevertheless, the science centres offer rich opportunities for investigative practical work.

4.7 ASSESSMENT OF PRACTICAL SCIENCE

See section 3.1.

In general, assessment does not bear down as heavily on Australian schools as in England, partly because of the lighter accountability framework. This is partly because there is no high-stakes assessment at 16: the only high-stakes assessment is the VCE at the end of secondary schooling. Consequently, for most secondary school classes, teachers are free to use practical work to support learning in whatever way they see fit.

5 EMERGING LESSONS FOR ENGLAND

1. In many ways, Australia in general and Victoria in particular is a useful comparator for England, being culturally and economically similar, with a secondary school system that is broadly comprehensive and a significant independent sector.
2. One aspect of Australian education that is strikingly different is the much lighter touch accountability system, with no inspectorate and less emphasis on exam results in school accountability. Despite this, Australia out-performs England in international comparisons. The significance of parent and student feedback is also striking.
3. The only high-stakes assessment in Victorian secondary schools is the VCE at the end of secondary schooling. There is no assessment before this, beyond the testing of literacy and numeracy in years 3, 5, 7 and 9. This means that the distorting effects of GCSE assessments at age 16 are absent and science teachers have a relatively free run until at least the beginning of VCE in year 11. In England, there could be a case for downgrading GCSE to assessments in maths and English only, thus freeing most subjects from the burden of assessment, which in science bears particularly on practical work. With the end of compulsory education moving to age 18, this could be a logical step for England. However, care needs to be taken: such a move might downgrade the priority given to science (as was the case when assessment of science was removed in primary schools).
4. We have had confirmation of our existing ideas about the purposes and value of practical work, and some new insights. In particular: "Teachers felt that authentic hands-on experiences are essential to stimulate curiosity. Unexpected outcomes are an important part of that authenticity. The cognitive dissonance between what is expected and what actually happens helps to strengthen conceptual change. The importance of the unexpected was reinforced by several of the students we spoke to".

5. The rich menu of out-of-school practical science within reach of most schools in Victoria – science centres, museums and universities – and the apparent readiness to use these opportunities, enriches practical science. The science centre model may be worth examining, including:
    A. their use of PhD students to teach visiting school students; and
    B. their outreach work with rural schools.
6. The VCE 'Season of Excellence' showcases the best work of students at VCE in public exhibition spaces. This not only creates a purpose for students to do well beyond an exam result and ATAR score, but also provides students with the opportunity to see 'what good looks like'. The Melbourne Museum is considering a similar approach to the new science investigation unit in VCEs. This could be a way of showcasing top science students in the UK, for example in the CREST or Extended Project programmes.
7. A large proportion of assessment within VCEs is trusted to the teacher. Guidance on appropriate approaches is provided in the 'study design' documents but teachers are given freedom to choose the most appropriate approach for their students. The suggested approaches to assessment are also varied and include video, annotated log books, media responses, presentations and practical investigation reports.

ANNEX 1: SOURCES OF EVIDENCE

A. DESK RESEARCH.

Main sources (accessed March 2016)
OECD Data website, Australian statistics, www.data.oecd.org/australia.htm

Science and mathematics participation rates and initiatives, Victoria Auditor-General's report, June 2012 www.audit.vic.gov.au/publications/20120606-Science-and-Maths/20120606-Science-and-Maths.pdf

The continuing decline of science and mathematics enrolments in Australian high schools, Kennedy, J., Lyons, T., Quinn, F. Teaching Science. Volume 60, Number 2, June 2014. www.eprints.qut.edu.au/73153/1/Continuing_decline_of_science_proof.pdf

Education policy Australia, OECD, June 2013 www.oecd.org/education/EDUCATION%20POLICY%20OUTLOOK%20AUSTRALIA_EN.pdf

www.ausvels.vcaa.vic.edu.au

www.education.gov.au/school-education

www.lmip.gov.au/default.aspx?LMIP/LFR_SAFOUR/VIC_LFR_LM_UnemploymentRateTimeSeries

www.moodle.asta.edu.au

www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0

www.abs.gov.au/AUSSTATS/abs@.nsf/mf/3218.0

www.acecqa.gov.au/ministerial-standing-council-on-school-education-and-early-childhood

www.education.vic.gov.au/about/department/Pages/factsandfigures.aspx

www.education.vic.gov.au/about/programs/learningdev/vicstem/Pages/centres.aspx

www.education.vic.gov.au/school/principals/curriculum/Pages/ib.aspx

www.stav.org.au

www.study.vic.gov.au/deecd/learn/study-in-victoria/en/school-system.cfm

www.vcaa.vic.edu.au/Documents/vce/extendedinvestigation/ExtendedInvestigationSD-2014.pdf

www.vcaa.vic.edu.au/Pages/vce/index.aspx?Redirect=1

B. HALF DAY VISITS TO FOUR SECONDARY SCHOOLS ON 7 MARCH, 8 MARCH AND 9 MARCH 2016.

Roxburgh College, 60–70 Donald Cameron Drive, Melbourne.
Publicly funded school; years 7–12, approximately 1,400 students. The school has exceptionally high ethnic diversity with many recent migrants. There are 36 mother tongue languages: 50% of students are Arabic, especially Iraqi. Two-thirds of students are male. The school has a substantial Applied Learning programme as well as the general academic VCE programme.

We met six teachers, including the Head of Science, at a roundtable discussion.
We met one technician.

School contact: Principal Fernando Ianni

Penleigh and Essendon Grammar School, Rachelle Road, East Keilor.
Independent fee paying school drawing on a culturally diverse part of Melbourne. K–12, organised into:

- K–6 girls' school.
- K–6 boys' school.
- 7–10 girls' school.
- 7–10 boys' school.
- 11–12 co-educational school.

Approximately 500 students in each, total 2,400.

School contact: Principal Tony Larkin

We met with the year 10 co-ordinator (who accompanied us throughout the visit), two roundtables of teachers, including the Principal, Vice-Principal and Head of Senior School; observed and spoke to students in three year 10, one year 11 and one year 12 science classes (biology, physics, and year 10 integrated topics). We toured all the secondary schools and met one technician.

Blackburn High School, 60 Springfield Road, Blackburn.
Publicly funded neighbourhood school; year 7–12. About 1,100 students.

School contact: Principal Joanna Alexander

We met with a roundtable of teachers, including Assistant Principal, Science Area Leader and Science Director of Learning. We met a roundtable of students from years 8, 9 and 11 and observed a biology lesson.

Melbourne Girls' College, Yarra Boulevard, Richmond.
Publicly funded school with a very high reputation in an affluent neighbourhood; years 7–12. About 1,300 students.

School contact: Principal Karen Money

We were shown round the school by two students, and met with a roundtable of 15 staff, including the Science Leader, who has a joint appointment at the school and the University of Melbourne. We met three students. We had a meeting with the Principal and toured the school, visiting year 7 chemistry and year 11 biology and chemistry classes.

C. A MEETING WITH PATRICK GREENE, DIRECTOR, MUSEUMS VICTORIA AND LINDA SPROAL, HEAD OF EDUCATION, ON 8 MARCH.

D. A MEETING WITH PROFESSORS RUSSELL TYTLER AND VAUGHAN PRAIN OF DEAKIN UNIVERSITY ON 9 MARCH, TO DISCUSS THE RECONCEPTUALISING MATHS AND SCIENCE TEACHER EDUCATION (REMSTEP) PROGRAMMES.

E. VISITS TO TWO SCIENCE CENTRES. THESE GOVERNMENT-FUNDED CENTRES ARE DESIGNED TO SHOW STUDENTS CUTTING-EDGE SCIENCE RESEARCH AND APPLICATIONS. TEACHERS FROM ACROSS VICTORIA BRING THEIR CLASSES TO THE CENTRES.

- Quantum Victoria on 7 March. Centre for physical sciences. Director Soula Bennett.
- Gene Technology Access Centre (GTAC) on 9 March. Director Jacinta Duncan.

ANNEX 2: EDUCATION IN AUSTRALIA – A BRIEFING NOTE

OVERVIEW [4]

Australia has a population of 23.5 million, and Victoria a population of 5.96 million (in 2015).[5] The majority of the population of Victoria is settled in or around Melbourne, which has a population of 4.5 million.[6]

Approximately 6% of the population is unemployed (1% lower than the OECD average),[7] with 13% of 20-24's are unemployed. Australia sits firmly in the middle of OECD inequality rankings (0.33 – where 0 is complete equality). The spend per pupil is $8,790 per student. The UK spends $10,055 per student (averaged across primary through to non-tertiary education).

EDUCATION [8]

Australia has fewer underperforming students than the OECD average but, within Australia, rural and indigenous populations have lower academic performance and less access to tertiary education than their national average: students in rural schools perform 56 score points lower than students in Australian cities or large city schools.

However, the Australian education system does have a strong focus on ensuring equity, particularly with respect to Aboriginal and Torres Strait Islander populations. This can be seen through the design of curriculums.

There are two national education goals (defined in the 2008 Melbourne Declaration):

- Australian schooling promotes equity and excellence.
- All young Australians become successful learners, confident and creative individuals, and active and informed citizens.

Compared to other OECD countries, Australia's teachers have a high teaching time and students spend a lot of time under instruction.

There is a high degree of school choice in the Australian system, with many institutions competing for enrolments. It has been suggested that this level of school choice may be driving segregation of students into different schools based on their socio-economic background.

SYSTEM STRUCTURE [9]

States and Territories have a lot of autonomy over schools and Vocational Education and Training in Australia. The education system is steered nationally through a series of agreements focused on funding and education priorities. A national evaluation and assessment framework exists but there is significant local interpretation, with each territory and state having its own school improvement framework. The Council of Australian Governments (COAG) and the Education Council coordinate national educational policy. [10]

Children start school with a Foundation year (called a Preparatory year) age 5, and must start primary school age 6. Students then have 12 years of primary and secondary schooling. In the final two years of secondary school (upper secondary, years 11 and 12) students can study for the Senior Secondary Certificate of Education, which is required for entry to most universities and vocational training options.[11] Upper secondary education (Yr11+12) is not compulsory in Australia. In 2013, 84% of 25–34 year olds attained upper secondary level education – above the OECD average of 82%.

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[4] www.data.oecd.org/australia.htm

[5] www.abs.gov.au/ausstats/abs@.nsf/mf/3101.0 (accessed 15.07.16)

[6] www.abs.gov.au/AUSSTATS/abs@.nsf/mf/3218.0 (accessed 15.07.16)

[7] www.lmip.gov.au/default.aspx?LMIP/LFR_SAFOUR/VIC_LFR_LM_UnemploymentRateTimeSeries

[8] www.oecd.org/education/EDUCATION%20POLICY%20OUTLOOK%20AUSTRALIA_EN.pdf

[9] www.oecd.org/education/EDUCATION%20POLICY%20OUTLOOK%20AUSTRALIA_EN.pdf

[10] www.acecqa.gov.au/ministerial-standing-council-on-school-education-and-early-childhood

[11] www.education.gov.au/school-education

Both general and vocational programmes are offered in upper secondary schools. In schools, upper secondary students can study units towards recognised Vocational Education and Training (VET) qualifications while completing their senior certificate. Vocational Education and Training (VET) in Australia is also provided at the tertiary education levels, and employers are well engaged in the system. VET facilitates entry into the labour market through; work study programmes, Technical and Further Education institutes, and private Registered Training Organisations.

Australia has the sixth highest graduation rate among OECD countries in academic programmes and the eighth highest graduation rate in vocationally oriented programmes. However, Australia is continuing to work on programmes to improve their tertiary education, particularly VET. The COAG has set VET targets to be achieved by 2020 including reaching a position where over three quarters of working age Australians have a Certificate III level qualification or higher.

The Australian Government has also set two national targets for higher education:

- Attainment: by 2025, 40% of all 25–34 year olds will have a qualification at bachelor level or higher.
- Participation: by 2020, 20% of higher education enrolments at undergraduate level will be people from low socio-economic status.

VICTORIA EDUCATION SYSTEM [12] [13]

There are over 2,200 schools in Victoria including 207 independent schools. There are four selective entry secondary schools aimed at high achievers (yr 9–12). Students apply to attend.

There are 915,159 pupils with 393,590 in secondary school. There are 41,117 teachers with 15,136 in secondary schools (Victoria State Government figures, 2015). The average class size is 21 students (the average across Australia is 24).

Education in Victoria is compulsory for children aged from 6–17 years. Students attend primary school from age 5–12 years, with the schools split into a prep class and six other year groups (years 1–6). Secondary school students are aged between 12 and 18 years old, and on rare occasions, can be up to the age of 20. Classes are divided into years 7–12.

There are four terms in the Victorian school year. School usually starts in late January or early February and runs until mid-December. There's a short holiday between terms and a long summer holiday in December and January.

Almost 25 per cent of students at Victorian schools are from language backgrounds other than English.

The school curriculum in Victoria depends on the student year level:

- Prep to year 10: AusVELS – The Australian Curriculum through the Victorian Essential Learning Standards.
- Upper secondary (years 11 and 12) – determined by the Victorian Certificate of Education (VCE).

AusVELS[14] define the pre-year 10 curriculum. The eleven-level structure reflects the design of the Australian national curriculum while retaining Victorian priorities and approaches to teaching and learning.

AusVELS incorporates the Australian Curriculum learning areas for English, mathematics, history and science only, other curriculum areas are aligned with a curriculum framework originally developed solely for Victoria – the Victorian Essential Learning Standards (VELS).

There are six science strands as part if AusVELS:

- Patterns, order and organisation.
- Form and function.
- Stability and change.
- Scale and measurement.
- Matter and energy.
- Systems.

All schools also offer extra-curricular programs with many options and experiences.

ASSESSMENT

During primary and secondary school (not including upper secondary) school student assessment is a combination of the National Assessment Program Literacy and Numeracy (NAPLAN) and teacher based assessments. NAPLAN is a national assessment for students in years 3, 5, 7 and 9, that is undertaken every year in early May. It focuses solely on numeracy and literacy.

In upper secondary (years 11 and 12) students follow the two-year VCE study programme.

[12] www.study.vic.gov.au/deecd/learn/study-in-victoria/en/school-system.cfm

[13] www.education.vic.gov.au/about/department/Pages/factsandfigures.aspx

[14] www.ausvels.vcaa.vic.edu.au/

As part of the VCE students can choose from more than 90 different subjects (30 of these are vocational options). A school decides what options they offer. More advanced university level units are also offered to students to take in their final year (year 12).

Each VCE study programme is broken into four units (numbered 1,2,3 or 4). Students can study some units from unit 1,2,3 or 4 in both their first and second year of their VCE.[15] Subject 'study designs' (specifications) are usually split into Units 1+2 (commonly studied in VCE year 1) and Units 3+4 (commonly studied in the second year of VCE).

To graduate the VCE students must satisfactorily complete a minimum of 16 units, three of which must be from the English group (with at least one unit from Unit 3 and 4 level), and with at least three Units 3 and 4 sequences in studies other than English. Of these 16 units, 13 can be from VET (vocational courses). Most students graduate with between 20 and 24 units.

The VCE (Baccalaureate), introduced in 2014, recognises students who choose to study both a higher level mathematics and a language in their VCE programme of study.[16] It was also an incentive mechanism to drive more students to study for this combination of subjects.

One study option within the VCE programme is the 'extended investigation'. Assessment is via teacher assessment (although the task is externally determined).[17]

> "The VCE Extended Investigation enables students to develop, refine and extend knowledge and skills in independent research and carry out an investigation that focuses on a rigorous research question. The investigation may be an extension of an area of curriculum already undertaken by the student or it may be completely independent of any other study in the student's VCE programme. Through this study, students develop their capacity to explore, justify and defend their research findings in both oral and written forms to a general, or non-specialist audience"
>
> Victoria Assessment and Curriculum Authority (VCA),
> Extended Investigation Study Design documentation

The Australian Tertiary Admission Rank (ATAR) is the scoring system used by tertiary education institutions (eg universities) to select students applying to their institutions. The ATAR score is used solely from this purpose and is derived from the VCE scores. It enables universities to compare students who have studied different subjects. Some subjects deemed more challenging will be given a higher weighting in the ATAR score. VTAC manage the process, passing on student ATAR scores and applications to selection authorities at tertiary institutions. The majority of universities use the ATAR score as part of their decision making. Some courses select up to 80% of students solely using ATAR.

ALTERNATIVE PROGRAMMES

VCAL (Victoria certificate of applied learning)

This is an alternative programme to the VCE studies in years 11 and 12. The programme includes practical work-related experience as well as literacy and numeracy skills.

VET (Vocational Education and Training)

This is a vocational programme of study followed in years 11 and 12. The programme includes workplace learning.

TEACHERS

Teaching is a graduate profession. The ratio of teachers' salaries to the earnings of tertiary educated workers is above the 2011 OECD average. Teachers have a heavy teaching workload, with more teaching time than in other OECD countries (873 hours per academic year in primary school compared to the OECD average of 790 hours). OECD data highlights the significant autonomy given to teachers in Australia compared to other jurisdictions.

During a teacher training degree, teachers have hands-on experience in schools through a supervised practicum placement programme, also known as 'teaching rounds'.

The Australian Institute for Teaching and School Leadership was created in 2010 to raise the quality of teaching and school leadership. The Institute sets standards and developed an accountability system for schools. Outputs from the accountability system are held on an Australia wide website called MySchool[18] – aimed at parents and the wider community.

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[15] www.vcaa.vic.edu.au/Pages/vce/index.aspx?Redirect=1

[16] www.education.vic.gov.au/school/principals/curriculum/Pages/ib.aspx

[17] www.vcaa.vic.edu.au/Documents/vce/extendedinvestigation/ExtendedInvestigationSD-2014.pdf

[18] www.oecd.org/education/EDUCATION%20POLICY%20OUTLOOK%20AUSTRALIA_EN.pdf

SCIENCE EDUCATION

Australia is ranked 10th (out of 37) in the 2012 PISA science tests.

AusVels science (Prep – year 10)

Within the Science AusVELS, there are six overarching themes that support the coherence and developmental sequence of science knowledge within and across levels. There are three key ideas: Science Understanding, Science Inquiry Skills, and the Nature of Science.

VCE science (years 11 and 12)

Several science subjects are offered as VCEs. These include: biology, chemistry, physics, computing, health and human development, and outdoor and environmental studies. There are two options students can follow within biology, chemistry and physics.

The assessment of VCE science varies depending on the units being followed. Units 1 and 2 (usually studied in year 11) are internally assessed or as stated in official documents "a matter for school decision". Assessment of Units 3 and 4 (usually studied in year 12) are supervised by the VCAA, however for biology the student's achievement is also determined by school-assessed coursework.

> "Percentage contributions to the study score in VCE biology are as follows:
>
> – Unit 3 School-assessed Coursework: 16 per cent;
>
> – Unit 4 School-assessed Coursework: 24 per cent;
>
> – End-of-year examination: 60 per cent."
>
> *VCAA Study Design document, Unit 3 and 4 biology*

OTHER INITIATIVES OF INTEREST

Australian Teacher Education Association (ATEA)[19]

The Australian Teacher Education Association (ATEA) is the major professional association for teacher educators in Australia.

> "The mission of the Australian Teacher Education Association is to promote:
>
> – The pre-service and continuing education of teachers in all forms and contexts;
>
> – The teacher education as central in the educational enterprise of the nation;
>
> – Research on teacher education as a core endeavour."

Science Education Technicians Association (part of ASTA, Australian Science Teachers Association)[20]

This group aims to connect School Science Laboratory Staff across Australia, enabling them to have a voice on national issues and to share ideas across state boundaries.

Science Teachers Association Victoria (STAV)[21]

Professional association for science teachers in Victoria. Predominantly volunteer led.

Science and Mathematics Specialist Centres, Victoria[22]

A system of six science and mathematics spread across Victoria, each with a different emphasis. The purpose of these centres is to give schools access to cutting edge research, equipment and experiences it is not possible to have in the classroom. The government supports school visits to the centres, with priority given to those schools in rural areas or with disadvantaged student bodies. The six centres are:

– BioLab – sport and human performance.

– Earth Ed – earth sciences and cutting edge technology.

– Ecolinc – environmental teaching.

– GTAC (gene technology access centre) – life sciences (cell and microbiology).

– Quantum Victoria – physics and maths through cutting edge technology.

– VSSEC (Victorian Space Science Education Centre) – exploring space.

[19] www.atea.edu.au

[20] www.moodle.asta.edu.au/

[21] www.stav.org.au/

[22] www.education.vic.gov.au/about/programs/learningdev/vicstem/Pages/centres.aspx

APPENDIX 3:
COUNTRY REPORT:
FINLAND

1 EVIDENCE GATHERING

This report has been written by Ginny Page and John Holman and is based on the following sources. Further details of the sources are in Annex 1.

A. Desk research.

B. Visits to three secondary schools, Viikki Teacher Training School on 20 April 2016, Helsinki Normal Lyceum on 21 April 2016 and Nöykkiö school on 22 April 2016.

C. A dinner discussion with teachers Pekka Peura and Eeva-Lisa Nieminen on 21 April 2016.

D. A meeting with Counsellors Anneli Rautiainen and Leo Pahkin at the Finnish Board of Education on 21 April 2016.

E. A meeting with Professor Maija Aksela, Director of the LUMA (STEM) Centre of Finland and the LUMA (STEM) Centre at the University of Helsinki, and Director of the Unit of Chemistry Teacher Education, on 21 April 2016.

The visits were organised by Professor Jari Lavonen of the Department of Teacher Education at the University of Helsinki, and accompanied by Professor Lavonen, Janna Inkinen and Dr Arja Kaasinen. Professor Lavonen also provided individual expert advice.

2 OUTLINE OF EDUCATION IN FINLAND

This is a summary: there is further detail in Annex 2.

Finland is one of the most sparsely populated countries in the European Union, and compared to the UK, its population of 5.5 million is relatively homogeneous. Finland is recognised as a major international leader in education, consistently ranked in the top tier of countries in the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). Attainment rates in upper secondary and tertiary education are higher than the OECD average, with one of the highest enrolment rates in upper secondary vocational education and training (VET) in OECD countries.

The fundamental administrative divisions of the country are the 313 (as of 2016) municipalities. These are relatively small authorities with a major role in governing what goes on in schools. Schools are owned by the local municipality and funded by central government and are small by English standards: in 2015, 17% of comprehensive schools had under 50 pupils and 9% had over 500 pupils. Parents may choose their child's school, but they generally go for the one that is closest, confident that it is good. Education is free at all levels up to and including university, and special needs education is provided within mainstream schools – there are no separate special schools and few private schools.

The education system in Finland comprises:

- Pre-primary (6 year olds).
- Basic compulsory education (primary and lower secondary) (7–16 year olds) in a comprehensive school.
- General academic education in upper secondary schools (about 50% of the population) for those or vocational education in vocational schools (16–19 year olds) (about 50% of the population).

Class sizes in comprehensive schools are relatively small, c.20 pupils, and there is no streaming or setting. Upper-secondary and vocational education for 16–19 year olds is flexibly organised and timetabled through the municipality to allow students to combine general with vocational learning.

The Finnish National Board of Education (NBE) is an agency of the Ministry of Education and Culture. The NBE prepares the content of the national core curricula and required teaching time, but municipalities are expected to work with their schools to devise local versions of the national curriculum. The national curriculum is reviewed every 10 years in a very consensual exercise involving parents, academics and employers. The core curricula for basic and general upper secondary education have recently been renewed and new local curricula based on this core curriculum are being prepared ready for first teaching later in 2016.

Teachers in Finland are highly trained. In lower and upper secondary education all teachers are required to hold a Master's degree in their subject, which most take alongside pedagogical training. The high level of training is seen as necessary as teachers in Finland are very autonomous professionally, and must be able to teach classes of very mixed ability in a way that supports success for all students equally. Teachers are also expected to participate in three days of state-funded in-service training every year, and many do more voluntarily.

2.1 ACCOUNTABILITY AND ASSESSMENT

There is a powerful 'culture of trust' of the teaching profession in Finland. Educational authorities and national-level educational policymakers are confident in teachers and their knowledge of how to provide the best possible education for young people. As a result, there have been no national or local school inspectors since the late 1980s, nor are there systematic evaluations of teachers.

There are no national exams for pupils in basic education in Finland. Instead, teachers are responsible for assessment in their respective subjects and courses, on the basis of the objectives included in the curriculum. The only national examination, the matriculation examination, is held at the end of general upper secondary education and is taken in four subjects in examinations of up to six hours each. Teacher assessment does not count towards the matriculation grade, although teachers do mark the matriculation exam, prior to a second marking by the matriculation board. Poor results in one exam can be compensated for by good marks in another.

The selection of students for upper secondary school is based on their grade point average for the theoretical subjects studied in basic education. Entrance and aptitude tests may also be used, and students may be awarded points for hobbies and other relevant activities. Commonly, admission to higher education is based on the results in the matriculation examination and university entrance tests.

Teachers are trusted to deliver reliable assessments, and schools are trusted to maintain the expected standards. There are no league tables and there is no system of external inspection – though there are regular evaluation visits by school supervisors from the municipality. School performance data is not published by government, although various media sources do collate and publish such data.

The education system is monitored through a process of regular, national sampling where around 10% of schools administer tests to their year 6 and 9 students in Finnish and literature or mathematics. The results are made available to the school and to the municipality for development purposes, and are also correlated with teacher grades to check that internal assessments are effective.

3 SCIENCE EDUCATION IN FINLAND

3.1 STEM

The government has prioritised STEM over the past 20 years through a major investment in LUMA, a national project to improve skills in mathematics and natural sciences. LUMA Centre Finland was established 8 November 2013, as the umbrella organization for LUMA Centres in Finnish Universities, to strengthen and promote their collaboration on national and international level. The LUMA Centre Finland network is directed and coordinated from the University of Helsinki. The LUMA Centre at the University of Helsinki includes seven so-called resource centres: BioPoP (biology), Geopiste (geoscience), F2k (physics), Kemma (chemistry), Linkki (computer science), LumO (pedagogy) and Summamutikka (mathematics). Activities include:

- Science clubs, camps, events, webzines and other activities for children and youth.
- Pre-service and in-service training for teachers, and interactive online web portals including videos and other materials as well as science classes and laboratories that support teachers in their work.
- Research on the teaching of mathematics and natural sciences and on the effectiveness of LUMA's own activities, and the development of them based on the research results.
- Collaboration with decision-makers and media, and especially with other active partners in the field.

3.2 SCIENCE IN THE SCHOOL CURRICULUM

The national curriculum in Finland is revised every 10 years, in a very consensual exercise involving parents, academics, employers and text book publishers. The Finnish National Board of Education (NBE) determines the core curriculum and the lesson hours associated with different aspects, but it is for municipalities and schools to make their own version and the potential for variation is significant. As part of this process of local curriculum development, teachers are encouraged to analyse key education questions, such as:

- What will education mean in the future and how can education prepare young people to the future?
- What types of competences will be needed in everyday and working-life situations?
- What kind of learning environments and practices or teaching methods would best produce the desired education and learning?

In August 2016 a new curriculum comes into force in Finnish schools. Some key changes are:

- A focus on seven generic competences and 21st century competences.
- At least one cross-curricular project each year.
- More collaborative classroom practices and project work.
- More teacher autonomy but also 'more responsibility for teachers'.
- An emphasis on the role of technology in teaching and learning.
- Emphasis on formative assessment for learning.

Despite some interpretation that these reforms meant the end to subjects in the Finnish curriculum, the Head of Curriculum Development at the Finnish National Board of Education has said: "Traditional school subjects will live on, though with less distinct borderlines and with more collaboration in practice between them". All students will continue to study some science all the way through, from basic education to the end of upper secondary. Science is taught as separate subjects – physics, chemistry and biology – and by specialist teachers who hold a major and a minor specialism. However, unlike England, biology is traditionally more closely associated with geography than with physics and chemistry.

Courses are generally taught to small groups of about 20 pupils over 6-week periods in lessons of at least 45 minutes (commonly 75 minutes). The Finnish curriculum is therefore comprised of many intense, short courses – some compulsory, some optional – over which teachers have significant autonomy in terms of content, pedagogy and assessment.

3.3 SCIENCE TEACHERS

Teachers in Finland are highly trained. In general education, all teachers are required to have a Master's degree and specialise in a major and minor subject. Biology and geography are frequently associated in this way, though a maths specialism generally gives the teacher more employment opportunities, as maths teachers are always in demand. In vocational education teachers should have a Master's degree or Bachelor's degree. The high level of training is seen as necessary, as teachers in Finland are very autonomous professionally.

Teacher training can be either concurrent, with pedagogical training integrated into the Master's programme (85% of students take this route), or consecutive, with the pedagogical training completed over one year after the initial degree. The consecutive model also serves those who decide on a teaching career later. This means that secondary school teacher training effectively takes five years. There are no national exams or standards involved in becoming a teacher.

However, according to the general national- and university-level strategies, teacher education should be based on scientific research and professional practices in the field and provide students with the knowledge and skills needed to operate independently as an academic professional and developer in their field. Specifically, teacher education programmes should include a high level of scientific knowledge and knowledge about general and science-specific pedagogies, as well as an understanding about the role a school plays in society and the skills teachers need to collaborate with other teachers and others in their wider communities. They must also develop skills in communication, ICT, academic research, curriculum planning and professional development.

Teachers can train at one of eight universities throughout Finland and every student teacher participates in teaching practice at a university teacher training school. In these schools, pupils may have up to half their lessons taught by a trainee teacher. In-school teaching practice constitutes around 25% of a teacher's traineeship. The teacher training schools belong to the universities' faculties of education but aim to retain strong links to the faculties of science as well. Teacher training is very competitive and universities are able to select from the top 25% of the cohort.

3.4 SCIENCE BEYOND THE SCHOOL CURRICULUM

The government has prioritised STEM over the past 20 years through a major investment in LUMA, a national project to improve skills in mathematics and natural sciences. It was suggested that this has been successful in terms of recruiting students to science and engineering courses at university, though perhaps less so for mathematics and physics. LUMA Centre Finland was established 8 November 2013 as the umbrella organisation for LUMA Centres in Finnish Universities to strengthen and promote their collaboration on national and international level. The LUMA Centre Finland network is directed and coordinated from the University of Helsinki.

4 RELEVANT FINDINGS

4.1 TYPES OF PRACTICAL SCIENCE

In the schools we visited, practical activities were relatively short (20–30 minutes) and straightforward. Most lessons were 75 minutes long, giving time for a short introduction to the ideas and the activity and for plenty of discussion afterwards. The discussion period was sometimes compromised, however, by the time taken by students and teacher to clear up after the practical.

Class size varied from 10 to 23, but was 15 on average among the grade 7–10 classes that we visited. Practical work was conducted in groups or in pairs and there was almost always more than one teacher, or trainee, in the classroom. In one class at Viikki school, additional support was provided in a grade 8 physics lesson by a special needs teacher who was primarily focused on two students in the room and helped them to keep pace with their partner in a practical activity on velocity.

The student:teacher ratio was crucial in enabling a significant amount of interaction during the practical. This was important, as sometimes relatively little introduction was given and students would embark on the activity with a limited understanding of why they were doing it. Groups involving more able students would work this out during the course of the activity, talking to each other and referring to the worksheets they were given. Struggling groups were quickly spotted by circulating teachers and prompted through discussion to consider the ideas behind the practical, and identify any misconceptions. This rarely seemed to cause students concern – one grade 9 biology student at Nöykkiö School cheerfully told us: "We learn best by doing, even when we make mistakes. And we always make mistakes". Teachers are exceptionally focused on the pupils in their class and on their individual needs during the lesson.

At Nöykkiö School, the Principal is trialling the separation of male and female students for grade 9 chemistry (and sport). We visited when the two groups were doing a practical to identify the presence of starch using iodine. The groups were of equal size but of differing energy levels, so timetabling the lesson concurrently in adjoining laboratories meant the three teachers involved could move between labs and be deployed where the need was greatest.

While we were told that group work was often a necessity as schools did not have sufficient equipment for pairs or individual working, a physics teacher told us that Nöykkiö School attempts to keep group size small in physics and chemistry to enable better student engagement with practicals. This didn't seem to be such a priority for biology in any of the schools we visited, where class sizes were bigger and practicals were less experimental. A biology teacher (and PhD geneticist) at Helsinki Normal Lyceum told us that even if she had the equipment in school for students to undertake real gene sequencing, she would prefer her method of using paper models as it enabled more time for discussing the concepts involved. Instead, she takes her grade 9 students to the LUMA Centre at the University of Helsinki to undertake gel electrophoresis using modern kit.

4.2 HOW FREQUENTLY?

In both Viikki and Helsinki Normal Lyceum, we were told that physics and chemistry teachers aimed at 100% of their lessons involving a practical. This may have been made easier due to their role as teacher training schools and hence with a plentiful supply of trainees to assist during practicals. But it was clear that the teachers believed in the absolute integration of practical work into science teaching and learning – in the schools we visited, hands-on meant minds-on. However, the proportion of practical lessons was estimated to drop to about 50% in biology, and generally decreased as students neared their matriculation exam at the end of upper secondary schooling.

Despite science lessons being predominantly practical, the simplicity of the activities meant that specialist laboratory space was not always necessary. In fact, labs appeared to be occupied between 45% and 65% of the time, and were often only half-full.

4.3 ATTITUDES TO PRACTICAL SCIENCE

We found the teachers we spoke to uniformly supportive of practical work as a method of engaging the minds of their students. This was particularly true of physics and chemistry teachers who routinely used practicals to give a 'real life' aspect to abstract or difficult concepts, and who found that practicals kept their students motivated to learn by engaging through a hands-on activity. There was a sense from teachers that complex investigations and/or equipment presented a barrier to this process and could inhibit the engagement.

A physics/chemistry teacher at Viikki School told us that her ideal practical would: "Be straightforward in terms of student understanding; use simple kit; be equally doable by all students independently; but also give results which had meaning and could be discussed within a group of students".

We asked the teachers we met why they chose to do so much practical work, and we were told it was in part due to the success of introducing more practical work in primary science. It was not clear whether increasing practical at secondary level had similar positive impacts. However teachers had a great deal of freedom about their choice of curriculum and pedagogy, were given a lot of trust by the authorities and their Principal, and only felt accountable to students and parents. Teachers could use their professional judgement to decide whether a particular approach was working, and adjust it wherever necessary. Therefore it's reasonable to assume that what we observed was successful, at least in terms of that particular school.

It was clear in all the schools we visited that the attitudes and motivations of biology teachers were different to physics and chemistry. This was in part because of a longstanding tradition whereby a significant number of biology teachers also specialise in geography (whereas chemistry teachers will often have physics as their other specialism). It was perhaps unsurprising then that we were told that fieldwork was quite common, particularly in Nöykkiö School, which is surrounded by forest, and where all grade 8 students undertake small studies in local ecology through 3 x 3 hour field trips over the course of a year.

4.4 FACILITIES AND FUNDING

In all the schools we visited, the laboratories were generally spacious (and rarely more than two thirds full) but were fairly basic when compared to counterparts in England. Gas, electricity and water were mostly available only at the side of the laboratory, and often with sufficient access for group work but not paired or individual practicals. Instead of using a central gas supply, Nöykkiö School used camping gas Bunsen Burners in their chemistry laboratories. At another school, we were told that students watched YouTube videos of bacterial growth because it was not possible for them to create bacterial plates in their own labs.

Similar to the joint specialisms of the teachers, the physics and chemistry department was separate from the biology and geography department in the schools we visited, and the laboratories in each department tended to serve both subjects rather than be specific to one science. Not only did this keep biology teachers at one remove from their physics and chemistry colleagues, it also presented some logistical issues if biology teachers wanted to use chemistry consumables or equipment in their laboratories.

We saw quite limited amounts of equipment – less than a class set of microscopes in one school – and broken equipment which the teachers did not have the time or skill to fix (with one fume cupboard being used as storage). Prep rooms were of variable size and tidiness, but much of the equipment was kept in the laboratories where students would take responsibility for collecting it, cleaning it and tidying it away.

In the schools we visited, IT was in common and effective usage, though often limited to quite basic applications such as visualisers to cover the theoretical part of science lessons. At Nöykkiö School, we also observed a grade 9 biology lesson where students filmed their dissection of a heart on an iPad, then edited their film with subtitles and music and uploaded it to the schools' learning platform (WILMA) before the end of the lesson. We were told that WILMA is used by students to keep all their work in one place, by parents to monitor their children's progress, and by teachers to assess their students' achievements.

4.5 TECHNICAL SUPPORT

None of the schools we visited employed science technicians and we were told that this was the situation throughout Finland. But in acknowledgement of the significant time that science teachers spend preparing for practicals and clearing up after them, they all receive an additional payment (which translates as a 'demonstration extra') on top of their normal salary. This is regulated through a national agreement, and works out at 20% of a physics/chemistry teacher salary and 5% for a biology teacher. This payment recognises the number of hours that a science teacher might otherwise spend on non-teaching activities such as preparing experiments, and the constraints placed on science teachers who might otherwise have more freedom about how many hours they want to teach in a week (upwards from a minimum of around 20 per week).

In addition to the 'demonstration extra', most schools pay extra to one or two science teachers for taking responsibility to order chemicals and equipment, organise the equipment storage and so on. The amount of this payment varies from school to school. In Viikki School, they pay about 16 hours per year to one physics teacher, and the same to one chemistry teacher.

4.6 PROJECT WORK

The schools we visited did quite varying amounts of project work as part of their science courses, though the teachers were aware that the new national curriculum required the introduction of interdisciplinary projects across the school. Helsinki Normal Lyceum did relatively little project work, similar to Viikki Teacher Training School where teachers were considering a new problem-based learning approach in science inspired by work undertaken by Michigan State University in the USA.

At Nöykkiö School, teachers focused project work on students selected for entry into grade 7 on the basis of their interest and aptitude in STEM, and were entitled to take a special STEM course, which was largely delivered in English. We received presentations from a group of such students who the year before had researched a variety of topics, from how plant growth changes with the direction of light, to the factors affecting climate change, to shifts in local forest ecology. They told us they liked practical work because it was intrinsically interesting, made concepts easier to remember, gave them the chance to "do something different than read a book, and enabled them to "make something happen".

It was very rare for students to undertake independent investigations, and it was relatively uncommon for them to be asked to plan their own experiments.

4.7 ASSESSMENT OF PRACTICAL SCIENCE

We heard very little from either teachers or students about the impacts of external assessment on practical science. For the teachers we spoke to, practical work was a means to achieve a stronger engagement with, and therefore understanding of, scientific knowledge. Therefore, the results would be evident in the choices students made to continue with science post-16, and in the results of their matriculation exam at 18.

Assessment in laboratories was mostly formative, and students were encouraged to self-assess where appropriate. For one physics/maths teacher, the best learning comes when his students take complete responsibility for their own assessment to the point of awarding themselves their own final course grade. This process involves continual reflection about what they understand, with his role being to guide them in ways to gain the knowledge and skills they self-identify as lacking.

However, teachers were expected to grade courses (and this expectation is likely to increase with the new curriculum), and these grades are important in determining which upper secondary school a 16 year old might enter. At Nöykkiö School, a physics/chemistry teacher designs simple summative tests for his courses, tweaking them each year to ensure variation between year groups. He told us he preferred not to assess directly through practical work because of the likelihood of unexpected incidents, but the tests he creates are based on the practicals the students have recently undertaken, giving him confidence that they can draw on the experience when sitting the test. He and his colleagues also use Fronter (a commercially available digital teaching and learning platform) to construct simple online tests, which the students seem to enjoy taking, and can even construct themselves.

At Helsinki Normal Lyceum, one physics/chemistry teacher gives all her grade 9 students a written report assessing how 'active' they had been in their practical work, and how well they had participated in discussions around experiments. She encourages her students to grade themselves as well, and if it differs from the grade she gave them she is open to negotiation, though this rarely happens.

4.8 TEACHERS' TRAINING AND CPD

The teachers we spoke to were passionate about the subjects that they taught, and confident about the way they taught them. We had heard much about the high status of Finnish teachers, and we asked teachers at Nöykkiö School where they felt that status came from. Their experience was not that the status was externally given to them – they are not paid significantly more than other professions – but that their judgement was not externally questioned either. There were not criticised or held to account by anyone other than students and parents, who they felt had a right to question their approaches, and who could be engaged in discussion if there were disagreements.

Being given so much autonomy relies on high quality training and development. As well as the length and integration of teacher training with Masters level science courses, what we observed in the schools we visited was the extent to which trainees were engaged in feedback discussion during their teaching practice. We heard it was common for trainees to have up to 10 'observers' sit in the back of a classroom and afterwards offer constructive comment on their lesson. More commonly, a trainee has the chance to reflect on their practice with an experienced teacher/mentor and three or four other science teacher trainees who sit in on their lessons. This culture of openness, as well as a willingness to engage with criticism and learn from others, felt very integral to the process of professional formation, and clearly enabled trainees to learn swiftly what they might do differently or better next time.

The LUMA (abbreviated from "luonnontieteet", the Finnish word for natural sciences, and "mathematics") programme – initially led by the Finnish Government but transferred to the University of Helsinki in 2003 – is credited with catalysing a positive change in primary teachers' attitudes to science and maths, but also with strengthening the professional development of secondary STEM teachers in terms of practical work. Combining research and development in teacher education, informal learning, and curriculum enrichment, the programme now has 13 regional centres based in universities around Finland, with the University of Helsinki taking a co-ordinating role. We were told by Professor Maika Aksela, Director of this network, about the importance of linking initial and continuing teacher education, of connecting informal and formal learning experiences in science for young people, and of close partnerships between science and education departments at Finnish universities.

At the University of Helsinki, for example, chemistry, physics and mathematics teacher training now starts in the students' second year where they can take a number of education courses within their science departments as an integrated part of their degree. Generous funding from the Finnish Government enables the LUMA network to develop and disseminate new models for teaching the sciences, maths and technology, and to offer 'real science' experiences for young people as part of professional development for teachers.

We heard very little directly from the science teachers we spoke to about formal CPD. It appeared that municipalities were responsible for co-ordinating and commissioning professional development, but the importance of this for science teachers was unclear.

5 EMERGING LESSONS FOR ENGLAND

The high quality of practical science in Finnish schools is related to the high level of training of teachers, because good specialist knowledge brings confidence in practical scientific situations. The level to which Finland's science teachers are trained is partly a result of close integration between science and education departments in universities over the course of a 5-year training programme. While England is unlikely to extend its period of teacher training, there is no reason why greater recognition and co-operation between science and education departments cannot start during undergraduate degrees and extend into PGCE, effectively lengthening the period of initial teacher formation. This might be something to consider trying out in a pilot.

Universities in Finland work in close partnership with schools designated as Teacher Training Schools. One particular advantage this gives is the opportunity for groups of trainees to learn together and form a very effective community of developing practice, observing each other's lessons, sharing ideas and giving constructive feedback. For the school, the benefit of having so many adults available to assist in science lessons could outweigh the disadvantages of investing in training teachers who may go on to teach elsewhere. Changes to teacher training in England have in many cases driven an unhelpful wedge between universities and schools which adopting the Finnish model could redress, as well as creating better trained teachers.

Finnish schools show that less can be more when it comes to practicals – use of short, simple (20–30 minute) practicals appeared successful in enabling students to understand concepts, and the high frequency of practicals meant that they were confident in their laboratories and adept in technical skills. Several teachers told us they try to do some practical work in every lesson, whether they were experienced or new teachers. One teacher said: "I can't imagine a lesson in which I did not do practical work of some kind". In order for this to be effective, lessons needed to be long enough to enable plenty of discussion afterwards, and relied on small classes often with more than one teacher to circulate among students as they worked through their practical with relatively little scaffolding from worksheets. Teachers are intensely focused on their students and their needs. With more timetabling freedoms there is the potential for more schools in England try out new ways of structuring their science courses, particularly at Key Stage 3, to accommodate this sort of approach.

For older, post-16 science students, exposure to more complicated equipment and the opportunity to undertake investigations could be gained outside the school by visiting a LUMA Centre. This had the advantage of delivering activities that are supposed to give the student the chance to behave like a 'real scientist' in a real science environment. We can see that universities and science centres in England could do more to explicitly offer these experiences to schools, though as we didn't visit any truly rural schools in Finland we weren't clear if the opportunities were equally available to those who lived some distance from a LUMA Centre.

The financial costs of not having science technicians were high; with science teachers paid at least 20% more on top of their normal salary. It would be worth Finland considering the savings they might make in their salary budget if they adopted the UK model of employing science technicians in schools. There were time costs too, with teachers using lesson time to help students clear up. One benefit was how habitually students collected equipment, cleaned it and tidied it away before the end of the lesson. This kind of responsible and efficient behaviour in the science lab is something that universities and employers in England have said they would like to see more of among school leavers.

The attitude to health and safety during practical lessons was mature and proportionate (generally). This may be a result of the pervasive culture of personal responsibility among Finnish teachers and students. But our impression was that schools in Finland may choose for students to conduct riskier practicals in a local university or science centre where there were facilities and staff to manage that risk. There are persistent claims that many schools in England, despite the presence of technicians and availability of advisory services, are placing unnecessary constraints on practical work due to concerns about risk. Exploring these claims and, where legitimate, the reasons behind them might inform strategies to develop proportionate approaches to risk management in practical science.

It was hard to know if the predominance of group work in practical science in Finland was a deliberate pedagogic choice or a result of limited equipment caused by modest budgets. Either way, it was an approach which worked well in mixed ability classes, and we saw plenty of examples of students helping each other work out what they were doing, and explain it to each other. This not only maximised learning: it was an important part of collaborative working in science and it may be that the removal of assessed coursework in science GCSEs and A levels provides an opportunity for schools in England to use group work more frequently and constructively.

As in other countries we have visited, there was less practical work going on in biology than in physics and chemistry. This is clearly indicated in the differences between the additional payments due to practical work made to physics and chemistry teachers (20%) compared to biology teachers (5%). One reason may be a strong tradition of dividing physics and chemistry from biology and geography, whether in teacher training or in the arrangement of departments in laboratories in schools. Some in England have suggested that biology has more in common with geography than physics, and Finland presents some warning about what could happen if this association was followed through into teacher training and/or curriculum development.

The absence of any external assessment before 18, or any external inspection of schools, clearly frees science teachers in Finland to teach and assess in a way they feel gets the best results for their students, whether or not that is measurable in terms of the matriculation exam. While teachers in England might feel that such a model is unthinkable among our policymakers, it is inevitable that many teachers themselves find it difficult to imagine 'success' in other terms because they have been both student and teacher in a system with very strict accountability measures. Encouraging teachers early and throughout their career to think deeply about what success means for them, in their classrooms and their laboratories, and to share this with colleagues, may seem like an obvious step but we think it may be one too infrequently taken.

The new national curriculum in Finland will require schools to introduce a cross-curricular project for each year group. Yet the lack of prescription from the Finnish National Board of Education about the nature of such a project has left some teachers feeling a bit mystified about what they are supposed to be doing. However, the fact that everyone is aware the curriculum won't be changed again for 10 years means there is plenty of time for teachers to develop strategies to deliver these projects, and to improve them over time. Politicians in England might consider that a longer reform cycle might allow for a less prescriptive curriculum.

Teachers in Finland do work long hours and are not highly paid, but the professional status they gain through their training and are accorded through the lack of external scrutiny means they choose to be committed to tasks they believe in, rather than feel obliged to do something they don't necessarily agree with. This autonomy means science teachers can make decisions about what they teach, and how they teach it, and under the new curriculum it is planned for levels of teacher autonomy to increase. Both Finland and England intend that their very different approaches to accountability are about ensuring higher quality teaching and learning. Further work looking at the relationships between science teacher autonomy, effectiveness, and accountability in these and other countries might suggest a new, more constructive model for implementation in England.

ANNEX 1: SOURCES OF EVIDENCE

A. DESK RESEARCH.

Main sources (accessed April 2016)
www.en.wikipedia.org/wiki/Finland

www.webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Finland:Overview

www.data.oecd.org/finland.htm

www.oecdbetterlifeindex.org/countries/finland/

www.localfinland.fi/en/statistics/Pages/default.aspx

www.oecd.org/eco/surveys/Overview_Finland_2014.pdf

www.oph.fi/download/175020_education_in_Finland.pdf

www.stat.fi/til/kjarj/2015/kjarj_2015_2016-02-11_tie_001_en.html

www.pasisahlberg.com/wp-content/uploads/2013/01/OECD-Finland-Lessons-for-Japan-2012.pdf

www.keepeek.com/Digital-Asset-Management/oecd/education/education-at-a-glance-2015/european-union_eag-2015-54-en#page1

www.oph.fi/english/education_system

www.oph.fi/download/151294_ops2016_curriculum_reform_in_finland.pdf

www.oph.fi/download/144754_Education_training_and_demand_for_labour_in_Finland_by_2025_2.pdf

www.minedu.fi/OPM/Verkkouutiset/2015/03/curricula.html?lang=en

www.oph.fi/english/current_issues/101/0/what_is_going_on_in_finland_curriculum_reform_2016

www.minedu.fi/export/sites/default/OPM/Julkaisut/2006/liitteet/eng_opm15.pdf

www.oph.fi/download/148966_Quality_assurance_in_general_education.pdf

www.enorssi.fi/ftts/about-us-1

www.webgate.ec.europa.eu/fpfis/mwikis/eurydice/index.php/Finland:Teaching_and_Learning_in_General_Upper_Secondary_Education

www.minedu.fi/OPM/Tiedotteet/2013/12/pisa.html?lang=en

B. HALF DAY VISITS TO SECONDARY SCHOOLS ON 20 APRIL, 21 APRIL AND 22 APRIL 2016.

Viikki Teacher Training School, Kevätkatu 2, 00790 Helsinki, Finland
Viikki School is part of the University of Helsinki and is one of the oldest Finnish schools, dating back to 1869. In 2003 the school moved into a new building, offering a modern environment for high quality, innovative teacher training as well as schooling for elementary pupils through to upper secondary students. The school has about 400 pre-school pupils, 500 7–19 year old students, 100 teachers, and at any time be hosting up to 250 teacher trainees. Post-16 entry is very competitive – only 15 out of 100 grade 9 students continue into upper secondary education here.

We observed and spoke to teachers, trainee teachers and students in a grade 8 physics class, and a grade 9 physics class. We also met with the Vice-Principal, school counsellor, and a physics/chemistry teacher.

School contact: Vice-Principal Marja Martikainen

Helsinki Normal Lyceum, Ratakatu 6, 00120 Helsinki, Finland

Helsinki Normal Lyceum is part of the University of Helsinki and provides comprehensive education for 12–16 year olds (currently 290 pupils) and upper secondary education (245 pupils). Established in 1867, it is considered one of the most prestigious schools in Finland. Pupils come from the surrounding area, but 25% are selected on the basis of test for Latin.

We observed and spoke to teachers and students in a grade 10 physics class, a grade 8 chemistry class, a grade 8 physics class, a grade 8 biology class and a grade 7 biology class. We also met with a physics/chemistry teacher and a biology teacher.

Nöykkiö School, Espoo, Finland

Nöykkiö School is a middle school for 450 grade 7–9 students in the Espoo region, bordering on Helsinki. While students come from the local area, the school also recruits around 24 students via an aptitude test into a special project-based STEM course taught in English. A group of these students, now in grade 8, gave presentations to us in English about the projects they had conducted the year before, and discussed with us their feelings about practical work.

We observed and spoke to teachers and students in a grade 8 biology class, a grade 9 chemistry class (split into two separate groups by gender), and a grade 9 biology class. We also met with a physics teacher and a biology/geography teacher.

ANNEX 2: EDUCATION IN FINLAND – A BRIEFING NOTE

ABOUT FINLAND

Finland's population of 5.5 million is scattered across a country of lakes and forests, with a population density of 18 people per square kilometre, making it one of the most sparsely populated in the European Union. The fundamental administrative divisions of the country in are the 313 (as of 2016) municipalities; relatively small authorities which together provide a large share of public services, including education, health care and social services. Spending has increased steadily in recent years, financed by municipal income tax, state subsidies, and other revenue, and some municipalities are struggling to align service provision with national standards.

Compared with the UK, the population is relatively homogeneous in terms of language and ethnic background, though immigration rates are increasing. Finland has one of the world's most extensive welfare systems, and performs well in many measures of well-being relative to most other countries in the OECD's Better Life Index, ranking at the top in education and skills, and above average in environmental quality, subjective well-being, personal security, social connections, civic engagement, housing and work-life balance. The challenge now is to maintain these standards in the face of a weakening economy.

THE FINNISH EDUCATION SYSTEM

Finland is recognised as a major international leader in education, consistently ranked in the top tier of countries in Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study. This has drawn significant attention from other countries hoping to learn from Finland's success (though it bears noting that its performance in PISA is not due to high achievers being exceptionally high, but because of the small gap between the low and the high achievers). Key aspects of the Finnish system include:

- Freedom to teach without the constraints of standardised curricula and the pressure of standardised testing.
- Teachers educated at least to Master's level including educational theory with time each week dedicated to professional development.
- Self-evaluation by education providers coupled with regular national tests in Finnish and literature or mathematics in Years 6 and 9 in a sample of c. 10% of schools.

The education system in Finland comprises: pre-primary (six year olds); basic education (7–16 year olds); and then two pathways which are inter-linked – vocational pathways leading to a polytechnic degree, and general upper secondary education leading to a university degree, a master's degree then doctoral study. Basic education is compulsory after which pupils have the choice to:

- Move into upper-secondary/high school (51% in 2013).
- Move to vocational schools (40%).
- Pursue other studies (3%).
- Do not continue immediately (9%).

In Finland there is a strong belief in the impact that quality of education[1] has on the employability of young people and long-term unemployment.[2] Hence developments in basic, upper secondary and vocational education, and courses at universities and applied universities are aimed at improving the competitiveness of the economy and employment rate. Examples of the success of the policy include:

- In 2015, 92% of students continued in upper secondary or vocational education.
- The Early School Leaving (ESL) rate students in Finland was 9% in 2015[3] and is below the Europe 2020 target 10%[4] (18–24 years old).
- 46% of 30–34 years old have completed a university-level qualification.[5] This is higher than the EU 2020 target (40%).

Attainment rates in upper secondary and tertiary education are higher than the OECD average, with one of the highest enrolment rates in upper secondary vocational education and training (VET) in OECD countries. School dropout is lower in Finland than in other EU countries, and is higher among people with an immigrant background. Adults (16-65 year olds) in Finland scored among the top skilled across participating countries in the Survey of Adult Skills, with younger adults (16-24 year olds) scoring higher than all adults in Finland and young adults in other countries. In the context of the economic downturn, unemployment remains below OECD average.

The Finnish Government envisages that at least 42% of 30–34 year olds will hold a higher education degree and that more than 90% of 20-24 year olds will hold a post-compulsory qualification by 2020.

Upper-secondary and vocational studies are flexibly organised and timetabled through the municipality to allow pupils to optimise their subject choices and, if they want, they can combine upper-secondary (often known as high school), with vocational learning. In order to make this possible, the schools organise their training provision in standard six-week modules. The general age to take upper secondary studies is from 16–19 years. However, many students are older, especially in vocational education.

Education is free at all levels up to and including university, including free school meals (which most pupils take up), free pupil welfare services, and free transport to and from school in basic education for those pupils who need it. Special needs education is provided within mainstream schools – there are no separate special schools. There is a tradition of participation in adult education and extensive provision for it.

Schools are owned by the local municipality and funded by central government and are small by English standards: in 2015, 17% of comprehensive schools had under 50 pupils and 9% had over 500 pupils. Parents may choose their child's school, but they generally go for the one that is closest – although there are some schools that offer a specialism in, for example, sport, and where there would be some kind of selection process.

[1] Berger, N. & Fisher, P. *A well-educated workforce is key to state prosperity* (2013). Economic Analysis and Research Network (EARN). Washington: Economic Policy Institute www.epi.org/publication/states-education-productivity-growth-foundations

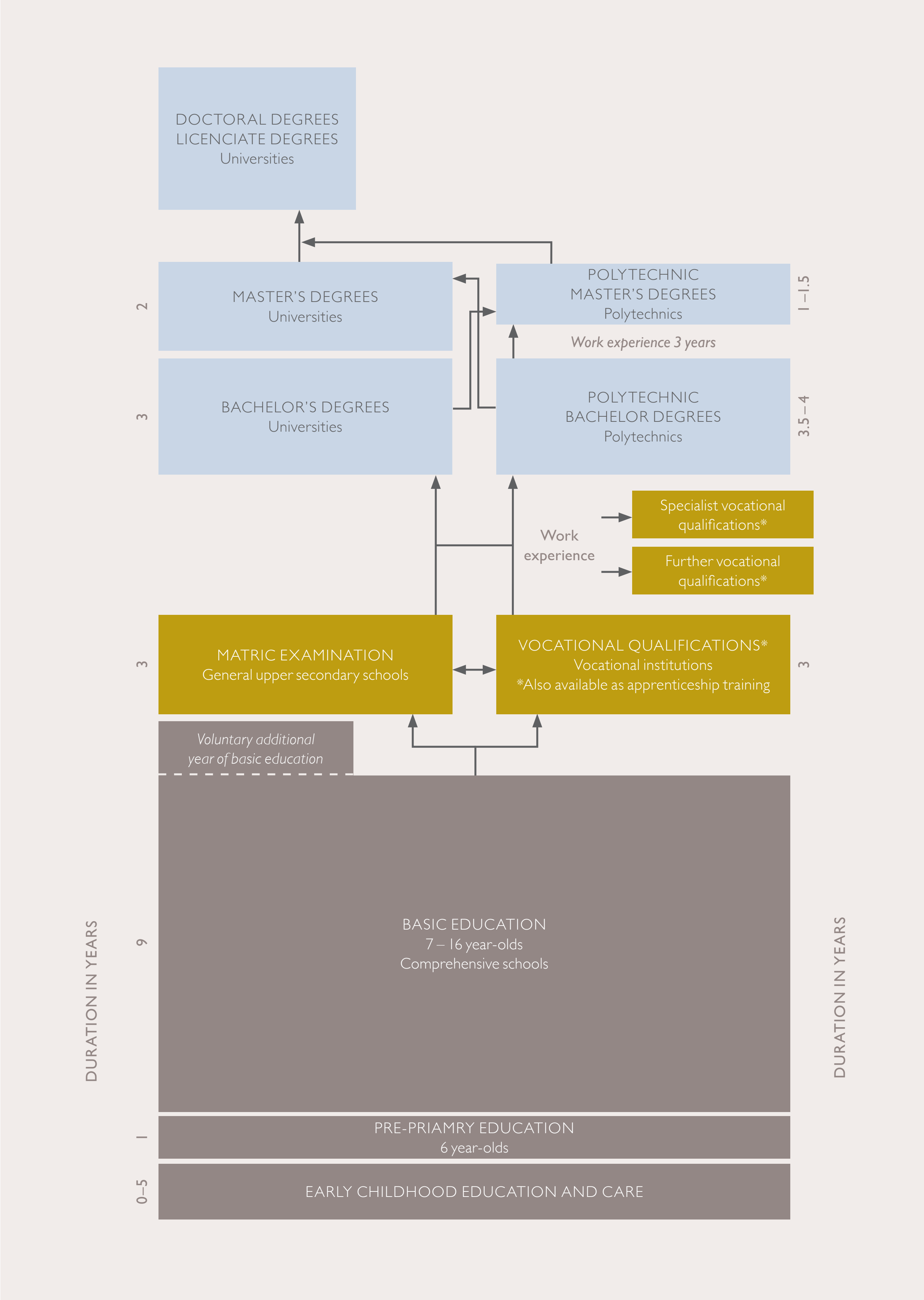
[2] Statistics Finland (2013). High level of education protects against unemployment. Source: Employment Statistics, Statistics Finland www.stat.fi/til/tyokay/2012/02/tyokay_2012_02_2013-06-05_tie_001_en.html

[3] Alueelliset koulutustilastot www.ec.europa.eu/eurostat/statistics-explained/index.php/Education_statistics_at_regional_level/fi Early leavers from education and training of 18–24 year students www.appsso.eurostat.ec.europa.eu/nui/show.do

[4] Cederberg M,. & Hartsmar N. *Some Aspects of Early School Leaving in Sweden, Denmark, Norway and Finland* (2013) European Journal of Education, 48(3).

[5] Eurostat (2016) Europe 2020 education indicators in 2015 www.appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

Figure 1: Education system in Finland



CURRICULUM AND ASSESSMENT

There are no national tests for pupils in basic education in Finland. Instead, teachers are responsible for assessment in their respective subjects on the basis of the objectives included in the curriculum. The only national examination, the matriculation examination, is held at the end of general upper secondary education. The selection of students for upper secondary school is based on their grade point average for the theoretical subjects in the basic education certificate. Entrance and aptitude tests may also be used, and students may be awarded points for hobbies and other relevant activities. Commonly, admission to higher education is based on the results in the matriculation examination and entrance tests.

The Finnish National Board of Education (NBE) is an agency of the Ministry of Education and Culture. The NBE prepares the content of the national core curricula and is in charge of the national joint application system for upper-secondary level education. The national core curriculum lays down curriculum content and required teaching time, but municipalities are expected to work with their schools to tailor its delivery, and teachers have considerable autonomy. The core curricula for basic and general upper secondary have recently been renewed and new local curricula that are based on this core curriculum should be prepared by the beginning of school year 2016–2017.

The new national level curricula emphasise learning of: competences such as ways of thinking, working, tools for working, contexts and attitude; employability; new pedagogy, new learning environments; and digitalisation of education. There are also new guidelines for inclusion and counselling in order to prevent early school leaving, drop out of young people from the society and unemployment.

The national core curriculum and the distribution of lesson hours for subjects are determined by the Finnish National Board of Education. It includes the objectives and core contents of different subjects, as well as the principles of pupil assessment, special-needs education, pupil welfare and educational guidance. The principles of a good learning environment, working approaches, and the concept of learning are also addressed in the core curriculum.

Recently, the government have also produced a separate curriculum aimed at immigrants and foreign language speakers in order to provide them with the linguistic and other capabilities required for the transfer to general upper secondary education.

The education providers, usually the local education authorities and the schools themselves, draw up their own curricula for pre-primary and basic education within the framework of the national core curriculum. These curricula may be prepared for individual municipalities or institutions or include both sections.

Apart from the matriculation examinations, assessment is done entirely by teachers. The NBE also produces national anticipation data on demand for labour and educational needs in support of decision-making. In addition, the Board supports regional anticipation efforts carried out under the supervision of regional councils. It obtains statistics and produces tools required for anticipation as well as estimates of labour demand and educational needs for regional councils in co-operation with regional councils, the Ministry of Employment and the Economy and the Government Institute for Economic Research (VATT).

Teachers are trusted to deliver reliable assessments, and schools are trusted to maintain the expected standards. There are no league tables and no system of external inspection – though there are regular evaluation visits by school supervisors from the municipality. School performance data is not published by the government although various media sources do collate and publish such data. To support teachers in the assessment, the core curriculum provides the criteria for good performance for assessment at the end of grade six and the final assessment in grade nine.

Upper-secondary pupils have to take a minimum of 75 courses over two to four years, which must include English, mathematics and mother tongue (Finnish or Swedish). Each course comprises three 75-minute lessons per week for six or seven weeks. At the end of their time in the school, pupils receive a diploma which sets out what they have studied; they also have to take matriculation exams which are the only external school exams in Finland.

Vocational studies are carried out in specialised vocational schools and can take three to four years, leading to specialist vocational qualifications. Vocational education and training is popular in Finland; more than 40% of the relevant age group starts vocational upper secondary studies immediately after basic education. The biggest fields are technology, communications and transport and social services, health and sports.

The Finnish National Board of Education decides on the national qualification requirement for each vocational qualification, determining the composition of studies and objectives, core contents and assessment criteria for study modules. It also includes provisions on student assessment, student counselling, on-the-job learning, special education and training, educational arrangements for immigrants and apprenticeship training. The content of local curricula is defined in the national qualification requirement as well. These requirements are drawn up in co-operation with employers' organisations, trade unions, the Trade Union of Education and student unions. National Education and Training Committees, local tripartite bodies as well as other representatives of working life take part in the curriculum work as advisers and consultants.

Higher education is provided by universities and polytechnics (also known as universities of applied sciences). Universities emphasise scientific research and instruction, whereas polytechnics adopt a more practical approach. Higher education institutions are very autonomous in organising their instruction and academic year.

There is restricted entry to all fields of study. The applicant volumes outweigh the number of places available. Therefore universities and polytechnics use different kinds of student selection criteria. Most commonly these include success in matriculation examination and entrance tests.

TEACHER TRAINING

Teachers in Finland are highly trained. In general education all teachers are required to have a Master's degree. In vocational education teachers should have a Master's degree or Bachelor's degree. The high level of training is seen as necessary as teachers in Finland are very autonomous professionally.

Specifically, according to the *Teacher Education Development Programme* (2002),[6] the teacher education programmes should help students to acquire, among other things, the following:

– High-level content/subject matter knowledge, pedagogical knowledge, pedagogical content knowledge, contextual knowledge and knowledge about nature of knowledge.
– Social skills, such as communication skills and skills to cooperate with other teachers and skills to use ICT.
– Moral knowledge and skills, such as the social and moral codes of the teaching profession.
– Knowledge about the school as an institute and its connections to the society.
– Skill to cooperate with other teachers and skills for the school–community (local contexts and stakeholders)–parents partnership.
– Academic skills, such as research skills.
– Skills needed in developing local curricula, the planning of teaching and organising the assessment of teaching and learning.
– Skills needed in developing one's own teaching and the teaching profession.

When these national-level aims are compared to the description of teacher professionalism,[7] several similarities can be recognised. The versatile knowledge base – including subject matter knowledge, pedagogical knowledge, pedagogical content knowledge and contextual knowledge; competence for networking and operating in partnerships and, moreover, competence for life-long-learning – are an essential part of Finnish teachers' competence.

Primary teachers are educated in five-year master level programmes (300 cp.).[8] The programme consists of studies in the major (140 cp) chosen out of education or educational psychology. The first minor is multi-disciplinary studies (60 cp.) – studies of the pedagogical content knowledge of school subjects at primary level. The students also choose another minor subject (60 cp.) and other optional studies, like communication and language studies (40 cp.).

Teacher training can be either concurrent, with pedagogical training integrated into the Master's programme, or consecutive, with the pedagogical training completed after the initial degree. The latter is the case for example in vocational teacher education. The consecutive model also serves those who decide on a teaching career later.

The Finnish National Board of Education (FNBE) is responsible for national-level implementation of educational programmes and strategies (eg ICT strategies) and for financing ICT tools and long-term in-service training programmes for teachers. For example, in year 2016 FNBE opened a call for projects emphasising the development of innovative learning environments in basic and upper secondary education and training of teachers in these environments.

At most levels of education, teachers are required to participate in in-service training every year. The state funds in-service training programmes, primarily in areas important for implementing education policy and reforms. Education providers can also apply for funding to improve the professional competence of their teaching personnel. The Osaava Programme (2010–16) is a national fixed-term programme for continuing professional development (CPD) aiming to ensure systematic CPD of staff in schools. The programme supports education providers to systematically and continually develop the skills and knowledge of their staff according to locally identified needs. Participants in Osaava and other government-funded CPD increased from 30,000 in 2009 to almost 70,000 in 2013.

Contrary to pre-service teacher education, the in-service education or professional development of teachers is the responsibility of the municipalities/cities in Finland. Therefore, municipalities have organised short in-service courses and professional development projects (PDPs) for teachers. Special centres for in-service training have been established in many municipalities to co-ordinate local development efforts and in-service training. Some projects have substantially benefited from local and national networking,[9] [10] and teachers' pedagogical associations also organise in-service training for teachers. For example, the Finnish Association of Teachers of Mathematics, Physics and Chemistry has annually organised in-service days for science teachers.

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[6] Teacher Education Development Programme. (2002). Helsinki: Ministry of Education, Department for Education and Research Policy.

[7] Teacher professionalism is a complex concept, and it has been defined in several ways. In addition, several other terms, such as effective, competent, expert, quality, ideal or respective teacher, are used to describe a professional teacher (Cruickshank & Haefele, 2001; Stronge & Hindman, 2003). Teacher professionalism also refers only to the status of teachers. It depends on school level factors and cultural and education policy factors in addition to individual characteristics of a teacher, like teacher's knowledge base, teaching philosophy and interaction and collaboration skills (Müller, Norrie, Hernández, & Goodson, 2010).

[8] One credit point (cp) equals approximately 27 work hours, including lectures, small-group work and self-directed learning.

[9] Lavonen, J., Juuti, K., Aksela, M., & Meisalo, V. *A professional development project for improving the use of information and communication technologies in science teaching* (2006). *Technology, Pedagogy and Education, 15*(2), 159–174.

[10] *Koulu Kaikkialla* [Omni School] is a network emphasising out-of-school learning and use of technology in this learning www.kaikkialla.fi / *Luma Suomi* ohjelma [STEM education network] is facilitating the teaching and learning of STEM subjects all over Finland www.luma.fi/suomi/ eNorssi-verkoston [Network of teacher training schools] supports the use of technology in pre- and in-service training of teachers (www.enorssi.fi)

However, there are challenges in Finnish in-service education. According to the TALIS survey, teachers are not so eager to engage in-service education as some other countries.

In February 2016, the Ministry of Education established the Finnish Teacher Education Forum aiming to foster the renewal of teacher education as a part of national reform program. The aims of the Teacher Education Forum are to prepare a development program for teachers' pre- and in-service education (life-long professional development), to support the implementation of the program and to create the conditions for the renewal of Finnish teacher education through development projects. The program should describe what kind of teacher education and continuous professional development of teachers are necessary to ensure that teachers are able to support students in the classroom to learn the competencies (knowledge, skill and attitude) needed today, tomorrow and in future. The forum will support teacher education institutes to create environments and courses where student teachers have possibility to become familiar with new pedagogy, learning environments and digitalisation of teaching and learning.

SCIENCE EDUCATION IN FINLAND

Finland changes its National Core Curriculum (NCC) every ten years and in August 2016 a new curriculum comes into force in Finnish schools. Some key aims are to:

- A focus on generic competences and work across rather than within school subjects.
- Collaborative classroom practices and project work.
- An emphasis on the role of technology in teaching and learning.

Despite some interpretation that these reforms meant the end to subjects in the Finnish curriculum, the Head of Curriculum Development at the Finnish Board of education said: "Traditional school subjects will live on, though with less distinct borderlines and with more collaboration in practice between them".

As a starting point in 2012, the government proposed that for Basic Education a pupil's minimum amount of lessons would be 222 in grades 1–9. Content in all subjects has been reduced, but more lesson hours would be given to Social studies, Physical education and Music & visual arts. In grades 1–6, 'integrated environmental studies' would include: biology, geography, physics, chemistry and health studies.

There would also be seven dimensions of broad-based competence:

- Thinking and learning.
- Cultural competence, interaction and expression.
- Looking after oneself, managing daily activities, safety.
- Multi-literacy.
- ICT competence.
- Competence required for working life and entrepreneurship.
- Participation, empowerment and responsibility.

Collaborative classroom practices, where pupils may work with several teachers simultaneously during periods of phenomenon-based project studies, are to be more emphasised in the new curriculum. All schools have to design and provide at least one such study-period per school year for all students, focused on studying phenomena or topics that are of special interest for students. Students are expected to participate in the planning process of these studies. School subjects will provide their specific viewpoints, concepts and methods for the planning and implementation of these periods. On what topics and how these integrative study periods are realised, will be decided at local and school level.

The following table outlines the distribution of lesson hours in the current general upper secondary education for young people. The average scope of one course is 38 lessons. Consequently, in order to reach the number of lessons, the number of courses on the time allocation table should be multiplied by 38. The duration of a lesson must be at least 45 minutes. The number of compulsory courses varies between 47–51, depending on the choice between basic and advanced syllabus in mathematics. The entire syllabus in general upper secondary education for young people comprises 75 courses. In addition to the minimum courses defined by legislation, schools may offer school-specific specialisation courses and applied courses.

Subject or subject group	Compulsory courses	Number of national courses offered as specialisation courses
Mother tongue and literature	6	3
Languages		
A-language, starting in grades 1–6 of compulsory education	6	2
B-language, starting in grades 7–9 of compulsory education	5	2
Other languages		16
Mathematics basic syllabus advanced syllabus	 6 10	 2 3
Environmental and natural sciences		
Biology	2	3
Geography	2	2
Physics	1	7
Chemistry	1	4
Religion or ethics	3	2
Philosophy	1	3
Psychology	1	4
History	4	2
Social studies	2	2
Arts and physical education	5	
Physical education	2	3
Music	1–2	3
Visual arts	1–2	3
Health education	1	2
Educational and vocational guidance	1	1
Compulsory courses	47–51	
Minimum total of specialisation courses	10	
Applied courses		
Minimum total number of courses	75	

Despite a downturn in mathematics, Finnish students remain one of the best performers among the OECD countries involved in PISA. Finland came in sixth place among the OECD countries in mathematics, third in literacy and second in science. Shanghai-China, Hong Kong-China, Singapore, Japan and Finland are the top five performers in science in PISA 2012. Pasi Sahlberg[11] has suggested that Finland's exceptionally good performance in science is due to:

- A redesign of Primary science teacher education over the past 20 years focused on increasing opportunities for experiential and hands-on science (and an increase in Primary teachers with science backgrounds).
- A redesign of the Primary science curriculum away from academic knowledge and towards hands-on experiments and problem solving.
- Coherence in the above two factors.

Finland remains the best in literacy and science among the European countries. Finland's proficiency in scientific literacy ranked in fifth place among all participating countries and economies. Finland's position was among the best in the OECD countries along with Japan, Estonia and Korea. Finland's average scientific literacy has dropped by 18 points relative to the 2006 survey, when the focus was on science.

The government has prioritised STEM over the past 20 years through a major investment in LUMA, a national project to improve skills in mathematics and natural sciences. LUMA Centre Finland was established 8 November 2013 as the umbrella organisation for LUMA Centres in Finnish Universities to strengthen and promote their collaboration on national and international level. The LUMA Centre Finland network is directed and coordinated from the University of Helsinki. The LUMA Centre at the University of Helsinki includes seven so-called resource centres: BioPoP (biology), Geopiste (geoscience), F2k (physics), Kemma (chemistry), Linkki (computer science), LumO (pedagogy) and Summamutikka (mathematics). Activities include:

- Science clubs, camps, events, webzines and other activities for children and youth.
- Pre-service and in-service training for teachers, and interactive online web portals including videos and other materials as well as science classes and laboratories that support teachers in their work.
- Research on the teaching of mathematics and natural sciences and on the effectiveness of LUMA's own activities, and the development of them based on the research results.
- Collaboration with decision-makers and media, and especially with other active partners in the field.

The operations on LUMA Centre are funded by University of Helsinki's Faculty of Science, cooperating institutions and companies, grant-giving foundations, and private donations.

More than 30% of tertiary graduates in Finland are in science-related fields.

[11] Pasi Sahlberg. *Finnish Lessons. What can the world learn from educational change in Finland?* (2015). Teachers College Press.