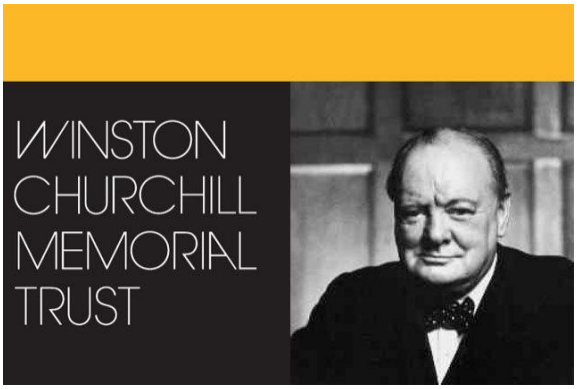
Increasing Achievement in Science Education: Learning Lessons from Finland & Estonia

Dr Neil Alan McIntyre

Churchill Fellow 2014



THE
MERCERS'
COMPANY

Contents

1. Introduction

Background of the Fellowship

The United Kingdom has a long and proud tradition of teaching science within its schools. Today it is widely acknowledged that in order for the UK to produce the scientists of the future it requires an education system which develops young people's skills in the subject.

"*The UK is a world leader in science and engineering. To maintain and capitalise on this position, the UK needs to strengthen its science, technology, engineering and mathematics (STEM) education*."[1]

The latest Programme for International Student Assessment (PISA) studies (published in December 2013) show British pupils (aged 15 years) lagging behind their peers from other nations in their academic attainment in science, reading and mathematics.[2] Indeed the top four performing nations/regions for science attainment are all Asian: Shanghai, Hong Kong, Singapore and Japan. Finland, previously

number one for science attainment among 15 year olds, has slipped to fifth in the latest world rankings*. However, Finland remains number one within Europe. Estonia came sixth in the world rankings and second within Europe for science attainment. Currently the UK is ranked twentieth in the world for attainment within the sciences. The results for mathematics and reading do not fare any better with the UK coming twenty-sixth and twenty-third respectively. Within the UK, Scotland performed slightly better than England in mathematics and reading but did more poorly in science within the latest PISA rankings. Northern Ireland came behind Scotland and England across all subjects. Wales did not perform well when compared to the other parts of the UK.

It is acknowledged that PISA studies have their critics who question the reliability of the rankings.[3,4] Nevertheless, many people take the PISA results very seriously. The fact that the UK is lagging behind other nations made headline news in December 2013.[5] Some argue that for the UK to compete with other nations in a global economy it must seek to improve its standing within international rankings.[6]

Until recently Finland led the PISA rankings in science education. The fact that many new primary school teachers have studied science education as part of their teacher education programme is cited as one possible reason for Finland's success.[7]

Like many teachers across the UK I was interested by the recent PISA results and questioned why British pupils were apparently behind in their learning compared to their peers in many other countries. Being a science teacher I was particularly interested in the science results and what lessons we could learn from countries that consistently score highly in international league tables.

My application for a Winston Churchill Memorial Trust Travelling Fellowship centred around my interest in Finland and Estonia's success. I was keen to discover good practice in Finland and Estonia from which teachers within the UK could learn.

* The term "world rankings" as used within this report refers to the countries that took part in the 2012 PISA studies.

Furthermore, this Fellowship was as much intended to find out what we are doing right within our schools, as it was to find ways in which we could improve, since it is acknowledged that there is already excellent practice within primary and secondary schools in the UK.

In addition to their high PISA rankings I also believed Finland and Estonia would be more culturally similar to the UK than the aforementioned countries/regions in Asia. Therefore it was my belief that any findings from my Fellowship may be easier to implement within the UK.

Finally, this report is a record of my own personal experiences whilst visiting schools in Finland and Estonia. In each country I visited two schools – spending one week in each. Therefore my experiences are based on a small sample of schools. It should also be noted that I am not an educational researcher - merely a science teacher with an interest in improving standards within the classroom.

2. Aims of the Fellowship

The short-term aims of the Fellowship were to gain an understanding of:

1. The Finnish and Estonian education structures.
2. The science curricula in both countries.
3. The training that is required to become a science teacher in Finland/Estonia.
4. The teaching methods employed within the science classroom.
5. The assessment methods used in Finland and Estonia to measure pupil attainment/achievement.

In addition to the aims above I was also interested in discovering other factors that may help explain Finland and Estonia's academic success - not just within the sciences but in general terms across all subject areas.

The long-term aim of the Fellowship is to enhance science teaching locally and nationally by learning from the Finnish and Estonian education systems.

3. Itinerary

Finland

Helsinki School of Natural Sciences (5th – 9th May)

The Helsinki School of Natural Sciences provides general upper secondary school education as well as a programme specialising in natural sciences for pupils aged 16-18. The school has approximately 700 pupils. One third of pupils follow the science programme and two thirds follow the general education programme. Since the school specialises in science education it receives extra funding to promote the subject. As a result of its specialism the school has a large selection of courses in mathematics, biology, physics, chemistry and geography.

Kulosaari Secondary School (Helsinki) (12th – 16th May)

Kulosaari Secondary School is an international school where teaching is conducted in both Finnish and in English depending on the course. The school provides lower and upper secondary education for pupils aged 13-18. The school has approximately 700 pupils. Kulosaari does not specialise in science education. Nevertheless, all pupils receive science lessons as part of the national curriculum.

Estonia

Reaalkool (Tallinn) (19th – 23rd May)

Tallinna Reaalkool (Tallinn Secondary Science School) was founded in 1881 making it one of the oldest schools in the capital of Estonia. The school provides education for pupils aged 7-18. The school specialises in science education – particularly within the upper secondary school. The school has some of the best national examination results within Estonia – especially in the sciences. Tallinna Reaalkool selects pupils based on their academic ability.

Viimsi (Tallinn) (26th – 29th May)

Viimsi school, in the suburbs of Tallinn, provides education for local pupils aged 7-18. Viimsi school does not have a specialism in science education. However, the school does place a strong emphasis on the subject and has a number of science clubs for younger children.

4. Findings

During my school visits I observed many science lessons. I also spoke to science teachers, head teachers and most importantly the pupils in an attempt to uncover good practice. Within this report I have attempted to link many of my findings to relevant literature.

4.1 Education Structure

Generally speaking, Finland and Estonia have very similar education structures. Children in both countries start school at the age of seven. Grades 1 – 9 (Figure 1) form the compulsory education that all children must undertake. By the end of grade 9 pupils have a choice and can either apply to study at a general upper secondary school or at a vocational school (equivalent to college in the UK). Results gained by the end of grade 9 often determine which route a child follows or indeed what upper secondary school a child studies at. Pupils sit national examinations after three years of upper secondary school before moving on to further study - such as University.

Figure 1 gives an overview of the education structure in Finland and the different options available to pupils. Estonia follows a very similar structure.

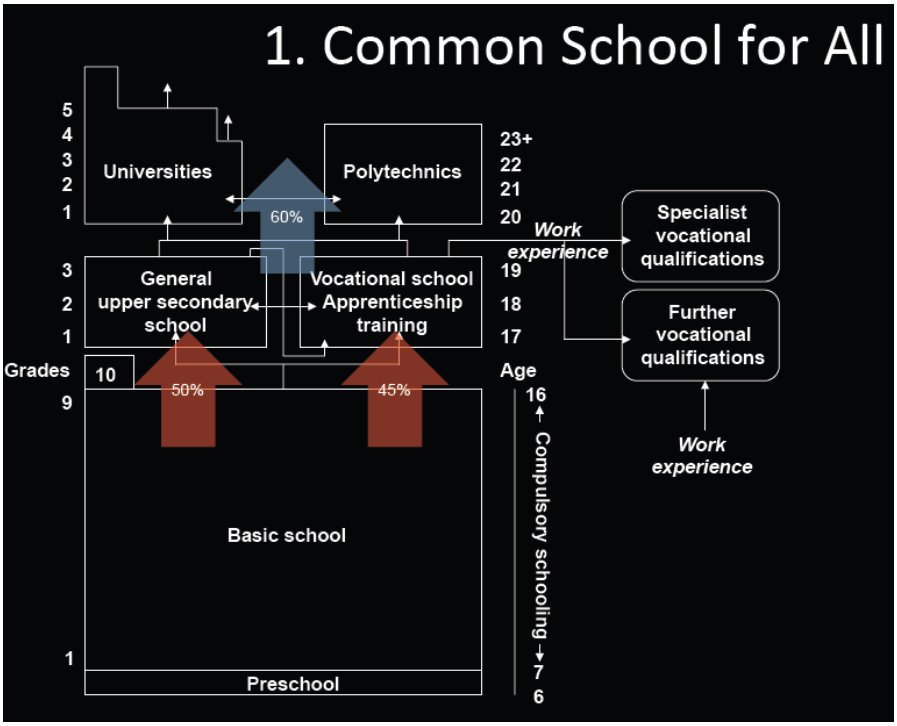


Figure 1: Education structure of Finland.

Many upper secondary schools in Finland and Estonia specialise in subjects such as science, languages, art, music *etc*. This is particularly true in large cities such as Helsinki and Tallinn. For example, the Helsinki School of Natural Sciences (Finland) and Reaalkool (Estonia) both had a focus on science education. These schools have a large range of courses in chemistry, physics and biology. Pupils with a particular interest in science often apply to study at these schools even though they are not always their local school. Therefore, many pupils travel some distance each day to study there. The Helsinki School of Natural Sciences receives extra funding for science education in comparison to other schools in the local area.

It should be noted that all general upper secondary schools, including those which specialise in certain subjects, teach a balanced curriculum incorporating all fundamental subjects. However, more time each week was given to the teaching of science subjects in specialist schools such as the Helsinki School of Natural Sciences and Reaalkool.

Scotland, in contrast to Finland and Estonia, currently has no school which specialises in science education[*]. In England, however, more than 350 science specialist schools exist out of a total of around 2200 specialist schools.[8]

The Finnish and Estonian national curriculum is extremely broad through to the end of upper secondary school in comparison to what is offered in UK schools. For instance, all pupils in Finland and Estonia must take compulsory courses in all subjects and learn "core" knowledge to the end of upper secondary school. Therefore, all pupils must take science based subjects up to the age of eighteen/nineteen. For those pupils with a particular interest in the subject there are optional courses in biology, chemistry and physics that the pupils can select. The flexible curriculum of core and optional courses allows each pupil to pursue an individual study programme.

During my school visits I spoke to a number of teachers about the issue of making subjects compulsory for pupils up to the age of eighteen/nineteen and whether they believed it was good or bad policy. In all cases teachers agreed that making subjects compulsory was good for pupils. Some teachers commented on the fact that most young people were unsure of what occupation they would like to pursue and therefore providing them with a broad curriculum kept many options open. Others thought most pupils were simply too young to choose subjects at sixteen years old.

Most pupils I spoke to enjoyed studying a broad curriculum up to the age of eighteen/nineteen. However, a minority of pupils did not. This was particularly true for pupils who had decided what career they wanted to follow after school and, therefore, knew what subjects they would like to specialise in.

[*] However, a new specialist science school is due to open in Glasgow in 2015.

Presently the uptake of science based subjects post-16 is poor across much of the UK according to a recent in-depth study by The Royal Society.[1] It appears Finland and Estonia avoids this problem by making *all* science subjects compulsory to the end of upper secondary school.

Key learning

- **Both Finland and Estonia have upper secondary schools which specialise in science education.**
- **Science subjects are compulsory for all pupils up to the age of 18/19 in both Finland and Estonia.**

4.2 Science Curriculum

Like the UK, Finland and Estonia follow national guidelines which outline what should be contained within the science curriculum in basic and upper secondary education. The guidelines outline the learning outcomes of the science modules. Core content is described which gives teachers a template for what should be contained within the course. However, no details are given on the methods for teaching the course and teachers have freedom to deliver it how they choose.

Throughout my time in Finland and Estonia I studied the content of national curriculum science textbooks to gain an understanding of the topics covered and gauge the level of work against my experiences of the Scottish science curriculum. My overall impression was that, in practically all cases, the content and level covered at specific stages was similar to that of the Scottish science curriculum. While there were some differences to the order in which topics were covered I did not form an impression that the work was more or less challenging. Initially this finding took me by surprise. I had presumed that children in Finland and Estonia would be ahead in their learning and therefore would be working on more complex work at a younger age than their peers in the UK. I expected this to be one reason which accounted for both countries impressive PISA rankings. Through classroom observations, discussions with science teachers and my analysis of national curriculum science textbooks I have come to the conclusion that the level of work covered by pupils in Finland/Estonia is similar to that in Scotland.

Key learning

- **The content covered in the Finnish and Estonian science curriculum is similar to that of the Scottish curriculum.**

4.3 Science Teachers

In practically all cases science teachers in Finland and Estonia have a Master's degree in their subject area as a minimum level of qualification. Almost all teachers I spoke to felt this was very important to maintaining good standards within the teaching profession. Moreover, teachers in Finland and Estonia also have to complete a teacher training course - typically for one year. In Finland part of the teacher training course involves undertaking an educational research project which helps teachers to engage in research, apply findings and to challenge and inform practice.

Clearly Finland and Estonia place great emphasis in ensuring teachers are of a high standard and value subject specialist teachers. While it could be argued that a high level of scientific knowledge is not required to teach science at a basic level, several recent reports highlight the importance of having science subject specialists at both primary and secondary school level in the UK. For example, a recent report by the Royal Society of Chemistry comments[9]:

"*Subject specialists are more likely to be able to answer detailed questions from pupils. They are more likely to teach beyond the textbook and have greater confidence demonstrating practical work to their class. Subject specialists have a deeper understanding, possess increased confidence, and improve pupils' attainment and attitudes towards their subject. Specialists, therefore, can have a positive impact on the decisions of students to continue studying the subject*."

This view is supported by anecdotal evidence during my Fellowship. In a number of schools I visited pupils told me they valued the fact teachers understood their subjects to a high standard. They felt the teachers could explain complex concepts rather than simply presenting facts for them to learn.

While visiting Viimsi school I was interested to discover that pupils are taught science from the age of ten by subject specialists. Indeed it was usual for children as young as ten years old to see as many as five different teachers per week for different subjects at Viimsi. I was told by staff that primary teachers in Estonia were not expected to be experts in all subject areas and teachers taught to their strengths.

"*If one thing is good for everything it is good for nothing*" (quote from a primary teacher at Viimsi school while discussing the need for subject specialist teachers).

Recently a number of scientific organisations have acknowledged the shortage of primary teachers who specialise in science education within the UK and the negative impact this is likely to have on future generations.[1,8]

"*Few primary teachers currently have degree-level qualifications in science and primary teaching continues to attract few science graduates".*[1]

"*Primary teachers with a first degree and Initial Teacher Education training qualification in science and mathematics represent only 3% and 2% respectively of the total number of primary teachers in England. These figures are likely to give a good measure of the scale and nature of the challenge confronting primary Science Technology Engineering Mathematics (STEM) teaching"*.[8]

According to the Royal Society of Chemistry, a primary school teacher should have at least an A-level qualification (or equivalent) in a science subject in order to be a specialist science subject leader. In addition, they believe that science subject leaders should also engage in sustained science-specific continuing professional development.[9]

At secondary level, there is presently a shortage of chemistry teachers in England with a degree in their subject. A similar story exists in Wales and Northern Ireland. In Scotland all secondary science teachers hold a relevant science degree. However, there are shortages of primary teachers who specialise in science.[9] Furthermore, a recent report by the Royal Society of Edinburgh highlights concerns about changes to entry requirements for initial primary teacher education in Scotland and the lack of a requirement for a science qualification.[10]

Recently the Royal Society of Chemistry has recommended that by the year 2020 every post-14 year old chemistry student should be taught by a chemistry-specialist teacher. In addition they recommend that in every primary school, the science subject leader should be a specialist.[9]

My visits to schools in Finland and Estonia show that both countries place a high value on the quality of their teachers and advocate children being taught by subject specialists from a young age. This, I believe, is a major factor in Finland and Estonia's success. Although we do not have science subject specialists teaching all children in the UK it is encouraging to see that a number of scientific institutions recognise this as a priority for educational reform.

Key learning

- **Science teachers are highly qualified in both Finland and Estonia. All subject teachers must have a Master's degree and complete a teacher training programme. Subject specialism is an important feature of Finnish and Estonian education. Children are taught by subject specialists from a young age.**

4.4 Teaching Methods

Over the four-week period of my Fellowship I observed over sixty hours of science lessons across the age range. During this time I witnessed many different styles of teaching. I was interested to find that the methods employed to teach children were similar to those used by teachers across the UK (Figure 2). For example, I observed many science teachers:

- Using PowerPoint presentations within lessons.
- Doing practical demonstrations in front of the class.
- Allowing pupils to carry out experiments/investigations.
- Using computer-based animations of scientific processes within lessons.
- Allowing pupils to research topics, write reports and give presentations.

Figure 2: Outdoor learning – classification of plants at Viimsi school - Tallinn (left). Using molecular model kits to look at chemical structures at the School of Natural Sciences – Helsinki (right).

It was clear throughout my school visits that science teachers could decide the best way to teach a topic and therefore had flexibility and autonomy. However, at no point during my Fellowship did I feel Finnish and Estonian teachers were teaching classes using vastly different approaches to what is commonplace within UK schools. Nevertheless, I did observe aspects of good teaching practice which merit further discussion.

Links with local Universities and Science Technology Engineering Mathematics (STEM) clubs

Most of the schools I visited had good links with local Universities. For example, at the Helsinki School of Natural Sciences students with exceptional academic records could study first year University courses during their time in upper secondary school. During my visit to Reaalkool I accompanied a school trip, led by an undergraduate University student, to a hydro-electric dam and wind farm as part of a renewable energy topic.

Viimsi school had a number of optional STEM clubs for children as young as eight. These included a science club, robotics club, sound and design club, multimedia club and nature club. Some of these clubs were led by undergraduate, Master's or PhD students who had an interest, or expertise, in the subject (Figure 3).

Figure 3: School trip to a wind farm and robotics club both led by undergraduate University students.

The range of STEM clubs on offer to very young pupils at Viimsi school impressed me a great deal. As a means of funding the clubs parents contributed ten Euros per month. However, external sponsors, Universities and the local authority also helped fund the clubs. As a result interest in the clubs had grown each year.

At Viimsi I had the opportunity to observe several science clubs with year two pupils - who were only eight years old. The clubs were practical in nature with the pupils undertaking experiments within a laboratory setting which they clearly enjoyed. The class was run each week by science specialist teacher Mr Peeter Sipelgas, who, along with other members of staff, had developed many inspiring ways to teach the children (Figure 4).

Learning about combustion – hands on!

Making bouncy balls from scratch (sodium silicate + ethanol).

Figure 4: Science clubs at Viimsi school for year two pupils (aged eight years old). Led by Mr Peeter Sipelgas (Chemistry teacher) – top left photo.

Research projects for senior pupils

In Estonia all upper secondary school pupils must complete a research project as part of the national curriculum. This is usually carried out in their 11th or 12th grade. Pupils select a topic from a subject in which they are interested and work under the supervision of a teacher. Many pupils choose a science related project.

The research project usually takes one year to complete. In this time pupils first research the area they aim to investigate. They then plan and carry out their research before finally writing up their findings. Throughout the process pupils follow national guidelines.

During my visit to Reaalkool I saw several science research reports and I spoke to pupils about the work they had undertaken. Below are some of the science projects covered at Reaalkool during my visit.

- Investigations into plant vegetation in an area of countryside.
- School students' views of organ donation.
- Acne occurrence among 7th, 9th and 11th grade students and treatment methods.
- Fossils found within Tallinn old town wall.
- Rate of decay of waste in different soil types.
- Wood ash as a cucumber fertiliser.

Although most of the science projects involved experimental investigation, some had to be completed by quantitative or qualitative research methods using a mixture of surveys and questionnaires. The reports varied in length but were generally between 30-50 pages long. Pupils developed many skills during the course of their research project. For example, each pupil had to review relevant literature. Many developed practical laboratory skills or an understanding of how to conduct quantitative/qualitative research. The fact that each pupil had to write a report detailing their findings meant that their scientific writing skills improved. At the end of their project each pupil gave a presentation where they outlined their findings. Therefore, presentation skills were also developed.

Pupils were marked on their research project from a combination of their written report and presentation. The marking was carried out internally by teachers and no verification procedures were in place to ensure standards were maintained between schools.

The fact that *all* senior pupils had to do a research project as part of the national curriculum impressed me. Pupils developed a number of skills and had the flexibility to research something that they were interested in.

Key learning

Although the methods of teaching science in Finland and Estonia are similar to those used in the UK many forms of good practice were observed.

- **Many schools had good links with local Universities in which undergraduate, Master's and PhD students supported schools.**
- **Viimsi school had an impressive range of STEM clubs for young children.**
- **As part of the Estonian national curriculum *all* senior pupils must undertake a meaningful research project which helps them develop important skills.**

Other findings:

During classroom observations and discussions with science teachers a number of other interesting findings were uncovered:

- **The Helsinki School of Natural Sciences was well resourced with scientific equipment. This can be attributed to the fact the school received extra funding for science. However, on the whole, resources in science classrooms were similar to what I have experienced within schools I have worked in. Science teachers often had to share classrooms due to a lack of space within the schools I visited.**
- **There appeared to be a lack of laboratory technicians in some of the schools I visited. Therefore there was less support which concerned some of the science teachers.**

4.5 Assessment

In the schools I visited pupils were continually assessed in science subjects during the course of their studies. Both formative and summative methods of assessment were used for recording/reporting purposes and to inform pupils of their progress. Written tests were the main form of assessment used at the end of science modules in most cases. Teachers kept records of grades and used these when reporting to parents/carers.

During grades 1-9 of basic education there are no national tests for pupils in Finland. The grades in the basic education certificate (the final certificate given at the end of year 9) are given by the teachers following national assessment guidelines. In Estonia there are national tests at the end of year 9 in Estonian, mathematics and an elective subject leading to a certificate. However, like in Finland, these examinations are internally assessed by teachers at the school who follow a mark scheme provided by the national examination board.

In Finland and Estonia upper secondary school ends with national school leaving examinations. These final examinations are set by an independent examination board in each country. The board also mark the examinations which guarantee uniform assessment.

In Finland each pupil sits national examinations in Finnish and Swedish; another foreign language; mathematics and a social or natural science subject.

In Estonia each pupil sits national examinations in Estonian, a foreign language, mathematics and at least one other subject*. In Estonia each pupil must also undertake a research project (see earlier in the report). In each country examinations assess the work covered during the three years of upper secondary school.

Teachers in Finland and Estonia are not required to collect evidence of work on each pupil for exam board purposes. Nor do they have to undertake verification procedures to ensure standards are maintained between schools.

During my visit to Viimsi school I asked a group of science teachers how they ensured standards were maintained between schools when most tests/projects were internally assessed and there appeared to be no verification procedures. Some teachers did concede that this may be an issue. However, one teacher summed up the mood of the group by saying.

"*We have a mark scheme and we stick to it*!"

Key learning

- **Teachers in Finland and Estonia mark tests, research projects *etc* using mark schemes provided by the education board. In many cases teachers are trusted to assess pupil achievement without the need for verification procedures.**
- **National school leaving exams are set and marked by an independent examination board in each country.**

***** For example, at Reaalkool the pupils could choose one subject from chemistry, physics, biology, geography or history.

4.6 Other factors which play a role in Finland and Estonia's success

Many factors influence how well pupils do at school such as the quality of the teachers/lessons, resources within the school and the support children receive from their parents/carers. In this report I have outlined issues which help explain why Finnish and Estonian pupils do particularly well in science. However, my time in Finland and Estonia also made me aware of other issues which I believe play a significant role in raising achievement levels across all subject areas and which may help explain, in part, Finland and Estonia's impressive standings within PISA.

Reporting

There is a strong link between the level of parental involvement in a child's education and their academic achievement.[11] Therefore, keeping parents/carers informed of pupil progress and how their child can improve is a very important area of education.

I was extremely impressed with the ways in which Finnish and Estonian schools use computer technology to communicate with parents/carers and pupils. Both countries use computer-based programmes to update parents/carers of their child's progress on a day-to-day basis. In Finland a system called "Wilma" is used by many schools. In Estonia "eKool" or "Stuudium" were the programmes used to report on pupil progress. These systems link the pupils, parents/carers and teaching staff together all the way through a child's education. Pupils, parents/carers and teaching staff each have a log-in and can perform a number of functions:

Teachers can input brief summaries of lessons (Figure 5), log attendance, set homework/test dates, grade pupils, upload course notes, alert good and bad behaviour, message classes, pupils and/or parents. When parents/carers log-in they can view the summaries of lessons so they know exactly what their child has been learning on a day-to-day basis (without ever having to ask!). They can also receive information about their child's behaviour (both positive and negative), read announcements, view the course notes that have been uploaded by the teacher, message teaching staff, view test dates or when homework is due and clear absences. Pupils can log-in and view the summaries of lessons, download course notes, check test scores/grades, read announcements, communicate with teachers, find out when homework is due or when tests are to be held. They can also register for courses. If for some reason a pupil is off school they can also use these computer systems to catch-up with work they have missed.

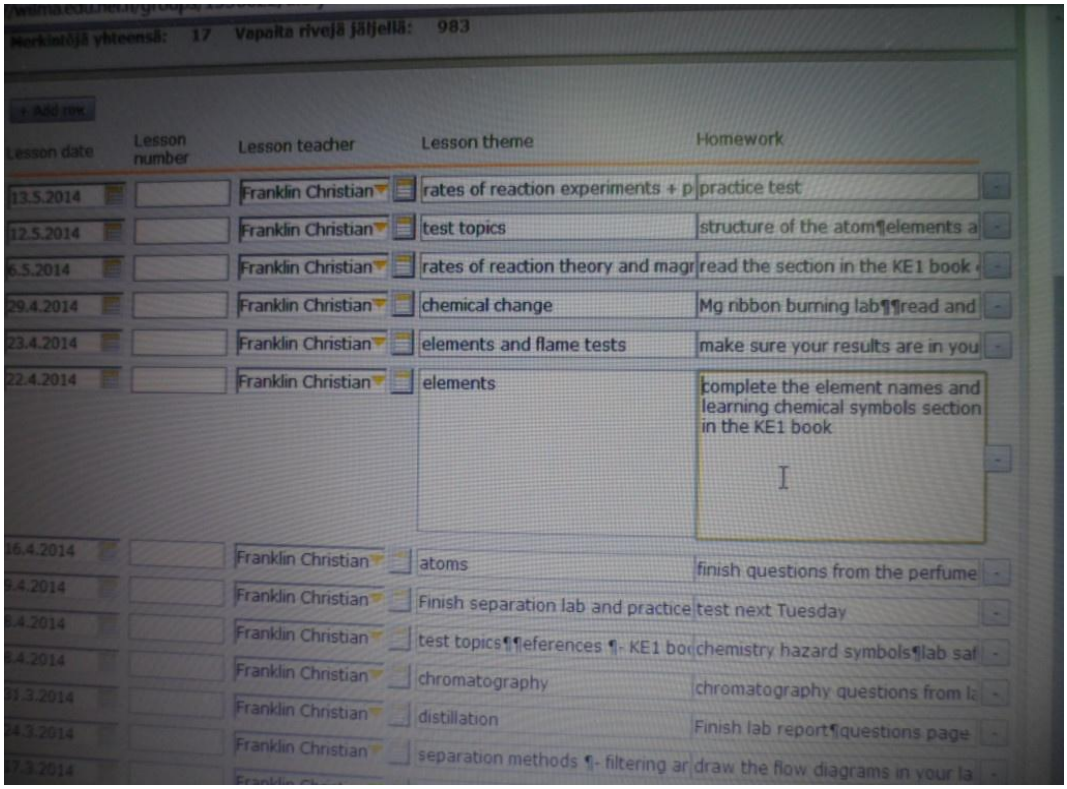


Figure 5: View from the computer screen of a science teacher inputting information about the lesson themes and homework using the computer programme Wilma. Pupils and parents/carers can also access this information when they log-in. This photo was taken at Kulosaari school.

The computer reporting systems help parents/carers to stay involved in their child's education. For example, they can download course notes to help with homework tasks – this is particularly useful for parents/carers of younger children. Parents/carers can stay informed and up-to-date with access to the system 24 hours a day, 7 days a week from a computer, or indeed their mobile phone. It should be stressed that *all* teachers use these tools for communication and not just science teachers.

All teachers I spoke to talked highly of these computer systems and felt they helped a great deal from both a teaching and reporting point of view. Teachers told me that they did not have to spend a great deal of time inputting information and they certainly did not have to forward plan weeks in advance.

Pupils also spoke highly of these systems. They told me they used them constantly to check test scores or when homework was due as well as looking at course notes. One girl told me she would use the computer systems to keep up with coursework while she travelled abroad with her family during term time.

I specifically asked the pupils if there were any negative points to Wilma, eKool or Stuudium. The only negative comment I received came from a boy who mentioned that eKool had made him lazy as he no longer needed to remember when his homework was due - he could just look it up on eKool! This, I thought, was a minor concern!

Although I never had the chance to speak to parents about how useful these computer systems are, a number of children told me their parents use them daily to check on their progress. With internet access so readily available parents can get updates on their mobile phones throughout the day.

To my knowledge no formal study has ever been undertaken to measure the impact of Wilma, eKool or Stuudium on raising attainment levels. Nevertheless, it is not unreasonable to suggest that any form of communication that creates stronger links between teachers, parents/carers and pupils has to be good.

Although schools within the UK often have different approaches to reporting on pupil progress it is fair to say many still rely on paper report cards sent home periodically throughout the year. What impressed me so much about the way Finnish and Estonian schools report is that information is passed on without delay. Parents/carers, therefore, can play a much bigger role in supporting their child.

I believe the use of computer-based reporting is one way in which Finnish and Estonian schools have narrowed the gap between the highest and lowest achieving students since parents can constantly track their child and feel more involved in their progress throughout school. I believe strongly that schools in the UK should learn valuable lessons from the way Finland and Estonia have embraced technology to enhance their communication with parents/carers and increase their involvement in their child's education.

Languages

The ability to speak multiple languages may seem unconnected to the achievement of pupils in science, or indeed most other subjects. However, my experiences in Finnish and Estonian schools has led me to believe the two are closely linked.

One common theme I encountered during my school visits was the ability of pupils to speak multiple languages. All senior pupils I met could speak a minimum of two languages fluently (usually Finnish/English or Estonian/English). However, many could speak three languages, and a few even four, by the time they were sixteen years old.

Finnish and Estonian children start to learn English at school in third grade (at nine years old). However, during my school visits I could have conversations, in English, with Finnish and Estonian children who were only eleven years old and, therefore, had only been learning English within the classroom for approximately two years. In discussions with teachers and pupils it became apparent why children pick up the language so quickly.

Children in both countries are exposed to the English language from a very young age. For example, a lot of television programmes are presented in English in both Finland and Estonia. Unlike many countries, Finland and Estonia do not dub English films/programmes - instead they have subtitles. Children also listen to music in English and play video games where they are exposed to the English language.

Although it was beyond the scope of my Fellowship to study this in any great detail I was continually impressed by the ability of pupils to speak multiple languages and began to question whether this had a knock-on-effect and helped pupils in other subject areas such as science.

The cognitive benefits associated with speaking two, or more, languages fluently is well reported within the literature.[12,13] Children who speak two, or more, languages fluently have a distinct advantage over children who are monolingual in areas such as problem solving and arithmetic. Anecdotal evidence from my school visits supports this. For example, during my visit to Estonia many pupils commented that speaking multiple languages made them better at solving problems which perhaps gave them an advantage when studying subjects such as science and mathematics. Other pupils told me that speaking multiple languages helped them when undertaking research projects in science since they could look up information in textbooks and websites in different languages and could therefore retrieve information from many different sources.

Key learning

- **Schools in Finland and Estonia use computer-based reporting programmes to keep parents/carers fully informed about their child's progress on a day-to-day basis. Therefore, parents can play a bigger role in supporting their child.**
- **Children in Finland and Estonia have impressive language skills which may help them in other subject areas including science.**

5. Conclusion and Recommendations

This report summarises my main findings during my four week Fellowship in Finland and Estonia. Many forms of good practice were uncovered during my school visits. For example, I was impressed by the fact that all children have to study science up to the age of eighteen in both Finland and Estonia. It is my opinion that having highly qualified teachers who are subject specialists contributes to the success both countries are having. The fact schools have good links with Universities and encourage STEM clubs also contribute to their success. In addition, Finland and Estonia have invested in good reporting methods which help parents/carers stay involved in their child's education on a day-to-day basis. I believe all these factors play a significant role in both countries academic success over recent years. However, I also believe there are other factors such as the ability of Finnish and Estonian pupils to speak multiple languages which has a positive knock-on-effect to other subject areas such as science.

It has become apparent from my Fellowship that the teaching strategies used within Finnish/Estonian science classrooms are similar to those used by teachers in the UK. Also, there appears to be many similarities in the content of the Finnish/Estonian science curriculum when compared to the Scottish curriculum.

Based on my findings it is my hope that the following recommendations can be implemented to improve science education within the UK (recommendations 3-5 are longer-term goals).

1. Schools should increase participation in STEM clubs – particularly by younger children.

2. Schools should seek to improve their links with Universities. This could be achieved by involving undergraduate students in running STEM clubs.

3. There should be better methods of communication between schools and parents/carers in all subject areas – following Finland and Estonia's example of using computer technology to track pupils' progress and keep parents/carers fully informed and more involved in their child's education.

4. Consideration should be given to making science courses compulsory within UK schools for pupils up to the age of eighteen.

5. Pupils should be taught science by subject specialists at primary and secondary school level. Science teachers should have at least the minimum level of qualification as recommended by the Royal Society of Chemistry. There should also be more collaboration between secondary school science specialists and primary colleagues.

It should be noted that many of the recommendations given here, as a direct result of my Fellowship, support those given in recent and significant publications by The Royal Society[1], The Royal Society of Chemistry[9] and The Royal Society of Edinburgh[10]. It is my hope that this independent report further strengthens their position on key issues affecting the future of science education within the UK.

6. Dissemination

Since my return to the UK I have:

1. Given a presentation to staff at Webster's High School, Kirriemuir, Angus, Scotland.
2. Spoken to the Parent Council at Webster's High School and to members of the Education Department at Angus Council.

I will now send my report to:

1. All Heads of Science and Head Teachers in the Angus local authority.
2. Education department – Angus Council, Scotland.
3. The Royal Society, The Royal Society of Chemistry, The Royal Society of Edinburgh, Science Community Representing Education and The Association of Science Education.
4. Mr Ian Menzies – Senior Education Officer for Science, Education Scotland.
5. Dr Alasdair Allan – Minister for Learning, Science and Scotland's Languages – Scottish Government.
6. Mr Michael Russell – Cabinet Secretary for Education and Lifelong Learning – Scottish Government.

7. Acknowledgements

I would like to thank the Winston Churchill Memorial Trust and the Mercers' Company for very kindly funding my Fellowship and for their continued support and interest in the project. I would also like to thank the following people for their help in both planning my Fellowship and for supporting me during my time in Finland and Estonia:

Helsinki School of Natural Sciences (Finland) - Mr Timo Hartikka, Ms Nina Arola, Ms Krista Sormunen and Ms Olga Sipila.

Kulosaari Secondary School (Finland) - Mr Lauri Halla, Ms Linda Eklof and Mr Christian Franklin.

Estonian Ministry of Education – Ms Ulle Kikas.

Reaalkool (Estonia) - Ms Jaana Roht and Ms Kersti Veskimets.

Viimsi School (Estonia) - Ms Karmen Paul, Ms Maarja Urb and Mr Peeter Sipelgas.

I would also like to thank the staff and pupils at each school for taking the time to speak with me during my visit.

Finally, I would like to thank Mr Eric Summers (former Rector of Webster's High School – now retired) and Dr Cara Matthew (Principal Teacher of Science at Webster's High School) for their support during my application for a Winston Churchill Memorial Trust Fellowship and for allowing me to take time out of school to undertake this worthwhile project.

Contact details:

Dr Neil McIntyre Email: namcintyre@hotmail.co.uk

Webster's High School, Prosen Road, Kirriemuir, Angus, Scotland, DD8 5BR.

Winston Churchill website link: http://www.wcmt.org.uk/users/neilmcintyre2014

8. References

1. *Vision for Science and Mathematics Education*. The Royal Society Science Policy Centre 2014. (See royalsociety.org/vision, accessed 1st August 2014). http://www.interacademies.net/File.aspx?id=25298

2. http://www.oecd.org/pisa/keyfindings/PISA-2012-results-UK.pdf (accessed September 2014)

3. Goldstein, H. (2004). *International comparisons of student attainment: some issues arising from the PISA study*. Assessment in Education, 11, 319-330.

4. Jerrim, J. *England's "plummeting" PISA test scores between 2000 and 2009: Is the performance of our secondary school pupils really in relative decline*? http://www.ioe.ac.uk/Study_Departments/J_Jerrim_qsswp1109.pdf

5. http://www.bbc.co.uk/news/education-25187997 (accessed September 2014)

6. http://www.bbc.co.uk/news/business-24988343 (accessed September 2014)

7. Sahlberg, P. *Finnish Lessons – what can the world learn from educational change in Finland?* 2010. Teachers college press, New York.

8. *Supporting Scotland's STEM education and culture – Science and Engineering Education Advisory Group (SEEAG) second report*: January 2012. http://www.scotland.gov.uk/Resource/0038/00388616.pdf

9. *Inspiring, engaging and expert: the formula for world-class science and chemistry education*, Royal Society of Chemistry Publication. (See www.rsc.org, accessed August 2014). http://www.rsc.org/globalassets/04-campaigning-outreach/inspring-the-next-generation/specialist-teachers-report.pdf

10. *Memorandum on entry requirements to programmes of initial teacher education in Scotland: a response by the RSE education committee to the General Teaching Council for Scotland*. (See www.royalsoced.org.uk, accessed August 2014). http://www.royalsoced.org.uk/cms/files/advice-papers/2013/AP13_05.pdf

11. Fan, X. (2001). *Parental Involvement and Students' Academic Achievement: A Growth Modeling Analysis*. The Journal of Experimental Education, 70(1), 27-61, and references therein.

12. Lauchlan, F., Parisi, M. & Fadda, R. (2013). *Bilingualism in Sardinia and Scotland: exploring the cognitive benefits of speaking a minority language*. International Journal of Bilingualism, 17(1), 43-56, and references therein.

13. Clarkson, P. (2006). *Australian Vietnamese students learning mathematics: High ability bilinguals and their use of their languages.* Educational Studies in Mathematics*, 64*, 191–215, and references therein.

9. Appendix – Other observations made during my Fellowship

* Generally speaking children in Finland and Estonia do not have to wear school uniforms (see pictures throughout this report).

* Pupils in Finland call teachers by their first name. The pupils seemed to think this was important. They felt it made teachers more approachable and less intimidating.

* There are 10-15 minute breaks between each lesson in Finnish and Estonian schools. Teachers and pupils thought this was very important. It gave teachers time to get organised and set-up for the next lesson and gave pupils the chance to unwind, have a drink or bite to eat and speak to friends briefly before the next lesson. Many Finnish and Estonian teachers were surprised to learn that there is no break between most lessons in Scottish secondary schools.

* Most classes in Finland and Estonia are mixed ability. They do not set classes by ability on the whole.

* Textbooks are free for pupils up to 9th grade in both Finland and Estonia. However, in upper secondary school pupils have to buy their own textbooks.

* In both Finland and Estonia there are free school meals for pupils up to sixteen years of age.

* University entrance exams are common in Finland. These are also becoming increasingly common in Estonia. Therefore, in Finland and Estonia it is not solely school exam results which determine whether a student receives a place at University.