Vision
for the future of science and maths education

THE ROYAL SOCIETY

Helping to shape the Royal Society's Vision for Science and Mathematics Education

Revised Scenarios following the workshop held in the Scottish Parliament in Edinburgh, Wednesday 11 September 2013

In collaboration with

Scotland's Futures Forum

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STEMEC

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A SCENARIO FOR 2030

Backstory

Education has changed dramatically following the snap election in 2017. Ongoing austerity gave fresh impetus to the importance of the knowledge economy. Policy makers recognised that STEM underpinned how we would manage future challenges, from climate change and increased life expectancy to the impact of technology and global inequality. They considered education a force for social good, and faced by both political apathy and political extremism, they saw STEM literacy as particularly crucial for democratic participation, enabling people to make informed judgements. The new coalition government made education its top budget priority, targeting early years and primary initiatives in particular, on the basis that this would foster lifelong learning.

The next two administrations continued this policy, given encouraging signs that government resources are being freed up by, for example, a reduction in crime and improvements in healthcare. There is also evidence of economic growth through innovation in ideas, technologies, products and processes, with increasing numbers of young people interested in entrepreneurship.

In the absence of limitless resources, university funding has been cut. Several institutions have gone to the wall, and some have gone private. They are successfully marketing high quality courses both at home and abroad through international distance learning consortia. Vocational education is highly prized, with close links between schools, colleges and industry, though some people complain the pendulum has swung too far in this direction. Industrial partnerships are commonplace because of tax breaks for participating companies.

University education faculties are thriving, however, after teaching was established as a Masters level profession in 2020, following the highly successful example of Finland. There are various routes to accreditation, both academic and vocational, drawing on the Engineering Council's approach to chartered engineer status. Since teaching is well paid and attractive, there are many more applicants than places, enabling careful selection. The courses have a growing international reputation for their relevance and focus on pedagogy. Traditional barriers between STEM subjects are disappearing, and any particular area is studied against a broad background. Teachers are licensed to teach particular age ranges and subjects: this includes primary teachers with STEM specialisms.

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Teacher education includes the importance of the public communication of science. There is increasing understanding of how to communicate effectively, thanks to the wealth of research created by the Masters courses. Educational policy and practice is also benefiting from ongoing advances in psychology and neuroscience into how scientific concepts are learned. CPD is not mandatory except for subject leaders, but there is an incentive to take it up since it is necessary for promotion. Twenty years ago, the majority of teachers complained that they would receive no recognition if they improved their teaching: today, improving their teaching is the only way to gain recognition.

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The government is piloting a controversial scheme of increasing class sizes in order to underwrite teachers' new enhanced pay scales, following the successful South Korean model. The scheme's supporters say technological developments, including accredited and appraised online resources, make it easier to cope with bigger classes. Teachers are now used to working collaboratively, both within and between schools, and with lecturers from further education colleges and mentors from industry and the professions. This keeps them up to date with their subject, and opens pupils' minds to real-world challenges and post-school opportunities. Pupils are encouraged to use examples from their own lives and communities, which research has shown leads to improved learning outcomes.

Testing and exams were dramatically reformed a decade ago, in recognition of teachers' know-how. There is a trusted internal evaluation system from early years until age 18, with teachers pooling their expertise to assess pupils across different schools. Assessment is much more creative, backed by strong educational research, and develops skills which employers value, such as problem-solving. Rather than focusing on low level facts, it concentrates on understanding and application. Employers seek evidence of pupils' potential rather than expecting them to arrive with job-specific skills. A number of schools enable pupils to put together a portfolio for assessment. Teachers capitalise on technology both to carry out assessments and to keep parents informed of their children's progress.

Pupils are encouraged to be open about their strengths and weaknesses, and to seek support when they have difficulties. The teachers are as keen to foster engagement and enthusiasm as achievement, and create opportunities which cater for different levels of ability. In maths, the focus has shifted from getting the right answer to developing understanding. Misconceptions allow the opportunity for discussion, with the teacher promoting reasoning and problem solving. Teachers say the new internal evaluation

system enables them to concentrate on the pupils' needs and the process of STEM subjects rather than teaching primarily with exams in mind.

The Royal College of Teaching, established in 2019, provides the kite-mark for educational resources, and oversees an official research programme into curriculum and assessment. Drawing further on the Finnish experience, since 2023 the best teachers have been paid a premium to work in deprived areas and with pupils who have the greatest learning difficulties. The Inspectorate's role is to support schools in continuous improvement.

Developments in neuroscience are having a strong impact on education. In the past, teachers were generally unaware of research findings since they didn't read academic journals. But for the past six years, relevant research has also been disseminated through teachers' training courses and professional publications. Psychology and neuroscience are now a key element of initial teacher education and CPD.

The timetable is much more fluid: PE and less intellectually demanding activities are generally scheduled first thing, the result of better understanding of adolescents' sleep patterns. This is resulting in better academic performance, greatest among pupils who were previously the lowest attainers. Physical exercise is standard, given the firm evidence that this improves academic performance.

Pupils are not only the subject of academic research, but help carry it out. They are particularly valued by the Citizen Science Alliance for their input to large scale studies across the country. Cheap mobile devices, 3D printers and cloud-based technologies are key to practical projects, which often take place outside the classroom. There is a growing body of work on creating projects which are engaging but low-budget. Secondary teachers have a goal of retaining the fun and excitement of primary lessons. Every science lessons has a hands-on component, but the advent of virtual labs allows pupils to carry out big science experiments that would otherwise be impossible because of lack of resources or for health and safety reasons.

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Teachers increasingly see CPD as vital for keeping on top of emerging technologies, since the pupils are often more aware of these and more expert in them than staff. Some pupils have themselves pioneered interesting breakthroughs and it is clear that some can be outstanding at computing even when they are less able at maths. CPD is also making teachers much more confident about running practical experiments: in the past, many claimed "health and safety" concerns as a way to avoid them.

School education is broad-based, ensuring that pupils keep their options open as long as possible. "STEM" is increasingly considered a misnomer, given a shift away from the silos of physics, chemistry and biology towards what has been dubbed "GRAIN": genomics, robotics, artificial intelligence and nanotechnology. Collaboration between teachers and lecturers is not only blurring the line between school and college but also between disciplines.

The Royal College of Teaching

An Address by Thomas O'Donnell, newly elected Fellow of the Royal College of Teaching for excellence in science and mathematics teaching.

When I joined the teaching profession 20 years ago, most of my colleagues were utterly demoralised. There was a sense of desperation and a lack of aspiration.

And now here we are, a highly regarded profession who can be trusted to self manage and self regulate. Different schools can choose to follow different models because of trust in head teachers and boards. There is a far lighter touch from Government, and key to that has been the Royal College of Teaching. It's not only a guardian of standards but also an important symbol. You'll all have seen the recent YouGov poll which showed public confidence in teachers is now almost as high as in doctors. Very different from the days when responsibility for most of society's ills were laid squarely at our door.

Our key loyalty is to our profession and our subject discipline. I'm proud to say that STEM has underpinned the technological innovations that let us work across groups of schools at home and abroad, and with other sectors of education and industry. When I first started, there was so much about teaching and learning that was woefully under-researched. Now that we're a Masters level profession, we're continually adding to our research knowledge. One quick example: just as we discovered decades ago that computer screens could be adjusted to help students with dyslexia and visual impairments, now we've discovered how to adjust the entire learning process depending on whether the pupil learns best through words, images or concepts, alone or in company. We used to be shockingly insular, but now we look at how creativity and innovation work in business, and draw on best practice wherever we find it.

And according to the research, I'm unusual – a male physicist who wanted to be a teacher. Apparently we prefer impersonal patterns to making eye contact. But our new opportunities for collaborative teaching have shown that many of our most hardened physicists are happy to make occasional forays into teaching and learning even if they wouldn't consider it as a full- time job. That helps ensure that those of us at the chalkface are aware of the latest trends. You can see from

the colour of my hair that I'm not one of the new breed who has come straight into teaching through a Masters course: I got accredited through the work I did while teaching. I found it really exciting to be able to reflect on what I was doing, and I got so many ideas from all the research about what works and what doesn't. It makes teaching an adventure: I'm not just doing the same old thing year after year.

Education, as we all know, used to be a political football, but we took the message from Japan that effective development meant a timetable of at least ten years. When I started teaching, STEM assessment was based on exercises that relied heavily on memorisation and recall, totally different from the way pupils might actually go on to use their knowledge, such as making personal decisions about health and diet. Our pupils were among the most tested in the industrial world. Test-and-inspection militated against teachers being creative and made our teaching plodding in order to meet the assessment requirements.

Would we ever have dreamed the Inspectorate could be our friends? And yet here they are, supportive, helping us towards best practice, creating a culture of innovation and acceptance. Failure no longer means pariah status, it means the first step on the road to improvement.

When I started, technology was just an add-on. Now it's an integral part of teaching and learning, and thanks to research, we know how to promote self-directed learning, crucial for grasping scientific concepts, and supported by properly accredited technology. And technology gives us access to online global communities which can help with lesson-planning, share tips on good practice, and boost our confidence.

We used to separate science and technology, which meant the pupils thought technology was interesting but science wasn't. We've got a much more integrated approach now. Decades ago, we had research showing that pupils did better in science when it was integrated with maths: it just took us a long time to teach that way. And our promotion of broad-based education may at last be bringing together the two cultures. I used the old-fashioned "STEM" when I should say "STEAM," including the arts.

I know many people think STEM should be compulsory until age 18, but I'm happy it's only till 15. Twenty years ago, pupils' interest in STEM subjects clearly waned as they went through secondary school, but that's no longer the case, thanks to enthusiastic and knowledgeable subject specialist teachers. I want volunteers, not conscripts. What we need is better post-compulsory provision which means pupils who aren't on a STEM track can move back if they want.

It's true that many of us with a STEM background tend not to be so good at people skills, which are crucial for working collaboratively and inclusively. But our subject leader training, internationally recognised, ensures that things run as smoothly as possible, and that we're all up to speed on the latest developments. Keeping things interesting and exciting for our pupils keeps things interesting and exciting for us. That's been critical for retention. I can remember when 30 per cent of science and maths teacher trainees didn't take up a post after qualifying. Now 70 per cent of staff take their full CPD entitlement.

I'm proud to belong to a profession which is creative, innovative and optimistic.

Basabi's Story

Basabi, aged 30, is a chemical engineering graduate, now working as a matter programmer. Headhunted by one of the country's largest multinationals, she uses computer based tools to design new materials at the sub-molecular level, collaborating with designers, material scientists and synthetic biologists. She is strongly committed to working with schools to promote STEM to pupils, conscious that she might easily have missed the chance of a scientific career. Mentors also include undergraduate ambassadors, final year students who sometimes decide to become teachers because they enjoy the outreach work so much. Retired and semi-retired people are also mentors, and teachers report that the range of ages has minimised discipline problems.

As a schoolgirl, Basabi loved Professor Brian Cox's programmes but never saw them as relevant to what she might do. Neither of her parents had gone into higher education and they had no background in science.

But when she was 14, she had the chance of joining an after-school club coordinated by STEMNET. This led her to a free university summer school where she first encountered chemical engineering. Her female mentor told her she would need good passes in chemistry and maths to get on the degree course. This was the first time she had had any information on a STEM career, and was just in time since she had been about to drop maths.

After graduating, she went into the water treatment industry and was sponsored through a doctorate. She enjoyed it, but is now thrilled to be working in a cutting-edge area she could never have imagined as a student.

As an industrial mentor, she wants to inspire and excite pupils, and bring the latest developments into the classroom. Several teachers have shadowed her in the lab as part of their CPD and she enjoys discussing with them how her work could be presented to different age groups. She visits schools, where the improved technician backup allows the pupils to carry out experiments she has designed, and she also talks to pupils via video link from her lab bench. She is not paid extra for this, but is given time off for outreach and preparation. If she decided to retrain as a teacher, she would be entitled to a bursary, but at the moment she enjoys her dual role.

She is about to be featured in a televised series presenting the work of five mentors nationwide. They include a personable young hedge fund manager, now a millionaire, who helps schools in deprived areas with maths teaching.

Basabi is particularly keen to encourage girls into STEM, given her own experience, though she finds them much more aware and motivated than she was at their age.

Lily's Story

Lily is 17, born during this century's baby boom. Neither of her parents is involved in STEM- related work, and her mother had a phobia about maths. When Lily was a toddler, her parents were invited to a presentation by the Institute of Physics which explained the job opportunities which would be available to their children, and the salaries they might expect. Lily's father thought this was ridiculously premature, and was shocked to discover the importance of early brain development. They were told that attitudes to STEM were a strong predictor of how well a child would do, and that parents and teachers could influence gender- based differences in attitude. Lily's parents found they held a host of stereotypical and misinformed views about suitable careers for their daughter, ruling out engineering as dirty and physically demanding, and computing because it involved working with machines rather than people.

Lily's mother, hearing that numeracy was just as important as literacy, was worried that she would give her daughter negative messages about maths. But she was encouraged through the National Numeracy initiative, discovering that such everyday activities as pairing socks, shopping, cooking and checking when the bus would come were practical maths that she could teach her daughter. National Numeracy showed Lily's parents how to promote maths through play, and they began to appreciate how maths was an intrinsic part of their world.

Lily was just beginning school when the new coalition government began its massive investment in education. A 2012 survey had found that the vast majority of schools had drastically reduced their careers provision. This was one of the first areas to be remedied, and Lily had careers advice starting in primary school. She was spellbound by the NASA mission to Mars, and decided to be an astronaut. Without her being aware of it, the primary school STEM subjects helped her develop her innate curiosity about her environment, encouraging her to observe things carefully and describe them precisely.

By the time she reached secondary level, the first cohorts of Masters level teachers were emerging. Research confirmed that girls performed better in STEM subjects when they were in a single-sex cohort, so although Lily was in a co-ed school, she found herself in all-girls' classes for a number of subjects. This resulted in fierce competition between the girls and boys to see which group performed better. The girls frequently won, which Lily reckoned was down to better cooperation and helping the weaker members of the class, which raised the average.

Far from developing a maths phobia, Lily is studying advanced maths, and is fascinated by calculus. She is in a minority, but a growing proportion of post-16s are continuing with general maths, thanks to the new emphasis on mathematical fluency. This focuses on being able to recall basic facts, alongside statistics and the application of maths. Careers education and presentations at parents' evenings has made pupils and their families increasingly aware that maths is important for everyone, including non-scientists. They include Lily's best friend Loredana, who wants to be a nurse.

One of the most popular classes, scientific literacy, is taken by all 16 to 18s in the school. It is not assessed, and aims to foster critical thinking and lifelong learning. It uses scientific methods of calling for and challenging evidence to look at real-life issues such as understanding risk and evaluating media reports.

Lily's school is involved in a highly successful regional initiative, based on the established Dutch scheme to bring science and maths together, which aims to make the natural sciences and technology more attractive to a broader range of students. Teams of teachers in science and maths have forged networks with universities, colleges and industry to develop up-to-date, relevant interdisciplinary courses. They are tackling topics ranging from heart disease and forensic science to bio-fuel and molecular gastronomy, letting the pupils see first-hand how useful and necessary maths is.

Lily attends classes both in school and at the local college, and is increasingly interested in art and music. She has long since abandoned thoughts of heading into space, and is considering becoming a cognitive ecologist. Careers advice reveals a growing demand for these specialists who design environments which enhance creativity, taking account of the brain, the body and the world around. Lily thinks this would be a perfect blend of her artistic bent and her interest in neuroscience.