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Do the maths

Experts say we're getting worse at maths and science. But now we have shiny new labs and cutting-edge teaching methods, were we really better off in the past? John Cornwell joins two leading scientists at their former schools to find out

"Five out of six applicants I interviewed recently for Cambridge entrance for engineering couldn't do a simple maths calculation: two to the power of 10." The tense, fast-talking professor has been complaining like this since we left Cambridge for Birmingham. "That's why," he goes on, "students doing university science and engineering spend their first and even second years catching up on the maths my generation did at school."

It's typical of the catalogue of woes I've been hearing from university teachers up and down the country. So I am driving Professor Roberto Cipolla back to his old school in Solihull to find out how science and maths are being done now compared to his day.

At Langley state comprehensive, the head teacher conducts us into the school's specialist maths area. The walls and an arch in the corridor are covered in decorative graffiti — mathematical formulae, equations and Einstein quotes. But how good is their maths? "So, what is two to the-power of 10?" the professor asks the class of 24 teenagers up to the age of 16.

It's as if a rattlesnake has reared its head. But there's just one lad with unruly black hair frowning hard at the ceiling. His hand shoots up: "1,024!" "Brilliant! How?" The kid has multiplied two by itself, then two by the result, then again and again 10 times in all: two twos are four, two fours are eight, two eights are 16, two 16s are 32… all in his head. The rest of the class look dazed. And it's "the rest" that worries Professor Cipolla. "There's always a uniquely bright kid in any school," he says. "But I'm interested in the 20% doing maths and science to A-level and beyond. When I was in the third year here back in the 1970s, we could all do two-to-the-power-of-10… two-to-the-power of 20, and so on, plus and minus: it's crucial shorthand when you're expressing numbers without using loads of noughts."

Maths and science skills are key to the nation's technology, commerce, industry, future prosperity. But are they in steep and irreversible decline? The

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Programme for International Student Assessment (Pisa), funded by the OECD, calculates a three-yearly league table of standards based on the abilities of average 15-year-olds. Its latest table, which covered 57 countries, shows that the UK has plummeted from 8th to 24th in maths, and from 10th to 14th in science.

Meanwhile key national studies have been ringing alarm bells. Starting back in 1951, says a recent report by the independent think-tank Reform, levels improved up till 1980, but declined rapidly after GCSEs were introduced in 1986. Content in science and maths curricula became broader, less demanding. Exams have been dumbed down: the pass mark for GCSE maths, for example, was lowered in the past decade to 20 out of 100. Teachers, moreover, have become increasingly demoralised by endless testing, including Sats, bureaucracy, and the government stranglehold on curricula, which suppresses initiative.

Professor Cipolla, born in Birmingham, the son of a migrant Italian ice-cream maker, came to Langley school in 1974 aged 11. He won a place at Cambridge in 1981. After taking a double first in engineering, he went to Balliol College, Oxford to do a doctorate before returning to Jesus College, Cambridge as one of the university's youngest professors. In the mid-1990s he invented an automaton that could move around, discriminating between objects of different shapes. The research won him the top international prize for robotics. The underlying principle was a built-in robust mathematical system known as an algorithm. Maths and engineering, in his view, are inextricable. He is now a world-renowned expert in the fields of artificial intelligence, computerised recognition and automation. Could Langley, or any average British school like it, produce a Cipolla today?

"Based on the national curriculum," he says, "pupils work in modules — discrete learning segments which give a smattering of popular knowledge across a wide area. This is where the problems begin." Modules aim to popularise scientific information in a "realist" fashion. How to calculate the carpeting of a room, understand trends in global warning, argue for and against the MMR vaccine, appreciate the reasons for washing hands before meals. When I ask a biology teacher at Langley how many periods they spend on Darwinian evolution, she says: "Typically they get one period in their whole school career." She adds: "I teach it with a Bible on one side of the desk and The Origin of Species on the other." Modularisation makes for enjoyable, polemical lessons in science, and lots of problem solving in maths, but as Cipolla observes, "It's significantly weak in fundamentals."

I'm bound for York to a different kind of establishment. Professor Dame Jocelyn Bell Burnell FRS was a pupil at the Mount School, an independent all girls Quaker school, in the 1960s, where Dame Judi Dench, A S Byatt and Margaret Drabble also spent their girlhoods. Burnell is one of the world's leading astrophysicists, and arguably Britain's top woman scientist. As a postgraduate student she was first to discover radio pulsars. She's passionate about the public understanding of science and the role of women in the natural sciences — not without reason. Her thesis adviser at Cambridge won the Nobel prize for his part in her pulsar discovery, but she was denied the award herself — a circumstance that outraged many of her peer scientists including the late Fred Hoyle.

An 11-plus failure, she came to the Mount aged 13. Like Cipolla, she's keen on fundamentals.

"I had a great physics teacher who said: 'You don't have to learn lots of facts, you learn a few key things and then you can apply and build and develop from those.'" Her physics teacher used to give her the run of a laboratory to do experiments by herself after supper every evening.

We're in one of the Mount's six science laboratories with a group of first- and second-year sixth- formers. Burnell has been looking back through physics exercise books from the 1950s. There are pages and pages on magnetism, once a big topic in O- and A-level physics but barely mentioned today. Science at the Mount now includes fields like particle physics, an area nonexistent when Burnell was young. She asks the class what the Cern

super-collider experiment is for, and they respond: “To find the Higgs boson particle.” But what’s that? One 15-year-old hazards: “They’re trying to replicate the conditions of the Big Bang.” A discussion about black holes, the Big Bang and radioactive decay leads to a Q and A about neutrinos, unknown back in the 1960s. The head of science, however, admits that their knowledge of particle physics is “qualitative” rather than “quantitative”: in other words it’s not underpinned by the mathematics essential to a true understanding of subatomic science — known as quantum physics.

The Mount, like Langley, boasts excellent maths and science teachers, as well as scope in the sixth form to learn outside and beyond the public-examination curricula. But privileged teaching and resources, even in the top schools, do not translate necessarily into science as a popular career option.

The Reform study claims that Britain is one of the few countries in the developed world where people routinely poke fun at maths and science and their “boffin” image. The girls at the Mount admit there’s peer-group stigma. “They think you’re, like, geeky,” says one girl. Only one pupil from the Mount chose to do maths at university last year. As we discuss this, a pupil from Singapore says: “In southeast Asia doing science is normal; in Britain it seems freakish.”

At lunch Burnell talks about the bad state of things: “We’re 7,000 school physics teachers short in Britain today, which means that the subject is being taught by a lot of unqualified teachers. Whereas we used to get the gold medal every year at the International Physics Olympiad, we barely manage to get bronze now. Oxford, Cambridge and Imperial College have just slipped in the world university league tables.”

And yet the perception of deterioration in maths and science for specialists and university entrants hardly tells the bigger story of the improvements in secondary-school maths and science over the past 30 to 40 years.

On a visit to my own old secondary school in east London, I found the contrast between the 1950s and today laugh-out-loud ludicrous. In my time, Canon Palmer school (originally Saints Peter and Paul) was a forbidding Edwardian two-storey building for 11-plus failures behind a high-wire fence off the Ilford High Road. Typical of most “secondary mods” of that era, and well into the 1960s, each year had a single “elementary” teacher for most subjects. There were 40 pupils to a form and the school-leaving age was 15. Maths never went beyond basic arithmetic. There was just one science period a week for each year, taken by a peppery Irishman in the school’s single laboratory. His equipment included an old Bunsen burner with which he revealed the mysteries of boiling water, and a temperamental air-pump that usually failed to demonstrate the effect of a vacuum on a candle flame. Only a handful of lucky ones, myself included, escaped at 13 after getting a second chance at the “scholarship”.

Canon Palmer, which became a comprehensive under the Wilson government’s educational reorganisation in the 1960s, is today on another planet. It boasts an impressive contemporary steel-and-glass building with an intake four times greater than my old school. With 1,200 pupils and a catchment area embracing two east London boroughs, it enjoys average class sizes of 24 and a 320-strong sixth form. There are eight science laboratories, six specialist maths rooms, eight maths and science teachers. Homework schedules (nonexistent in my day) demand 16 hours a week. Ninety percent of the sixth form went to university last year, half of them science students, and there were 43 As and Bs in A-level mathematics. Talk of slippage in A-level standards for maths and science is hardly a big deal for a generation that never even got to do O-levels or GCSEs.

In the bad old selection days, only those who passed the 11-plus (about 25% of those leaving primary schools) made it to the local state grammar school with a chance of staying on till 18 and making it to university. Professor Geoffrey Raisman FRS, one of Britain’s top neuroscientists (he discovered the principle of brain “plasticity” in the late 1960s and works on spinal-cord regeneration), is typical of a working-class scholarship-boy success of the 1950s. He went to Roundhay school in Leeds, an all-boys inner-city grammar school. “Most of us went to university from the sixth form,” he tells me, “and two of us, including me, got into Oxford in 1958. I was only 17.” Professor Raisman insists that the key to good education is a teacher, of any

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subject, who stimulates your imagination and desire to learn. He was fortunate, he says, to have had a brilliant history teacher. “He opened up 19th-century European history, and opened up my mind.”

The comment echoes the view of many top scientists I’ve spoken too, including Professor Lord Martin Rees, astronomer royal, president of the Royal Society and master of Trinity College, Cambridge. “I was at Darwin’s old school, Shrewsbury,” he tells me. “As in Darwin’s day, the school was interested in developing character rather than subjects!”

Raisman did chemistry, physics and biology at A-level, but he recollects that the science teachers, while good, were not inspiring. “I found maths very hard… the teacher’s classes were worthless and the subject unpopular: no history, background, application. I gave up maths after O-level out of sheer fear.”

Another familiar aspect of those inner-city grammar schools was the harsh discipline. “The headmaster was a bully,” remembers Raisman. He also recollects anti-semitism on the part of some teachers: 10% of pupils were Jewish. Roundhay today is a comprehensive. Typical of many schools in inner cities of northern England, it is multiethnic. “On a recent visit,” Raisman says, “I saw on the playing fields little girls dressed from head to foot in full Muslim dress. They were running around enthusiastically, playing with boys of all ethnicities, some in western shorts and T-shirts. They now occupy the same poor streets as the Jews in my day. It’s a poignant rerun of the struggles and self-sacrifice of the older parents and grandparents.” Today Roundhay boasts 12 specialist maths classrooms and 14 laboratories. The majority of its sixth form went to university last year, three of them to Oxbridge. Significantly, despite more than a fifth of its sixth form studying science and maths, not a single girl will do natural sciences at university. Three girls, however, are due to study for pharmacy qualifications, an indication of the importance of early job qualifications in deprived areas.

At Langley, Professor Cipolla had asked the class of 24 how many wanted to be scientists after university. Three put their hands up: one boy choosing chemistry, another archeology, and a girl who wants to be a pathologist. When Burnell asked the Mount girls the same question, only one girl volunteered. She said she wanted to do forensic science, and admitted the influence of TV’s CSI.

The issue of women in science, half the population’s pupils and students, has been thorny for generations. Burnell tells me that before she went to the Mount she attended a state school in Ulster where the boys did science and the girls needlework and cookery, so girls never even got started. In the past, there were even perceived gender differences among the sciences. Alan Cuthbert FRS, emeritus professor of pharmacology at Cambridge, tells me that when he expressed an interest in doing biology at his technical college 50 years back, the principal said: “You should have gone to the girls’ school up the road.” Now the opportunities in science for school leavers are said to be at last equal for boys and girls. But Professor Michael Reiss, the education expert who resigned from the Royal Society over the evolution-creationism spat, tells me self-selecting gender biases still exist. “It’s interesting that admissions for chemistry at university are definitely 50/50 for men and women. Yet women still don’t show the same interest in physics, where men predominate. Women, it seems, prefer their science to be tangible.”

The problems for career women scientists are formidable, and discouragement oozes down from the postdoc labs to the undergraduates and into the schools. I’m talking to a 28-year-old research scientist in applied physics at Cambridge who wishes (for obvious reasons) to remain anonymous. “There’s been a steady increase in women opting for science careers, but many start to drop out after the postdoctoral stage. That’s a loss not just for women, but for the country. You do a PhD, which usually follows a first-class honours degree, and you’re lucky to be earning more than £22,000 a year as a postdoc researcher, and there’s still a mountain of student debt to pay off.” Women, she says, are often treated as second-class citizens in the lab by male colleagues. “You work a seven-day week and unlimited hours; but you get rude comments if you dress in a feminine way, wear make-up or jewellery, a kind of soft-blackmailing to conform.” In her own case, she admits, there was a domestic

problem too. “If a woman is in a live-in relationship or married, the demanding hours and low salaries can be vexatious to male partners: men often can’t see why we work so hard for such poor pay. They resent the fact that we can’t just drop everything to go out for the evening or be there to cook dinner. If the man moves to take a better-paid job, in London say, they don’t appreciate the woman wanting to stay in Cambridge, which is after all the UK’s top science university, where researchers are proud to be. In my case the tensions ended in divorce.”

Despite tales of demoralisation, poor rewards and unrelenting competition at the top, there are stunning stories of dogged individual triumph against adversity, involving both women and men. Professor Carol Robinson FRS of Cambridge University is a world leader in the field of mass spectrometry and the study of molecules. She left school in Essex at 16 and went to work for six years as an unqualified lab technician at Pfizer, the pharmaceutical company. She spent her evenings and spare time studying for national certificates, then did a degree in chemistry for which she got first-class honours, followed by a PhD at Cambridge. After marrying she took an eight-year break to have her three children and bring them up. Nevertheless, she went back and soared to the top. “Taking time off to raise a family seemed to me the right thing to do,” she says. “Yet it was hard to take that break because of the need to keep up with information technology.”

Peter Atkins FRS, an Oxford professor and one of the world’s leading physical chemists (his textbooks have huge international sales), tells a similar story. “I dropped out of my state school in Amersham at 16 and got an unskilled job. I did my A-levels at night school, but I was turned down by Southampton University when I applied to do chemistry. Leicester accepted me, fortunately, and I stayed on to do a PhD… the rest is history.”

But the concern about overall standards in Britain today, according to Celia Hoyles, professor of maths education at London University, is not for the brilliant few who make it to the top, nor even for the 20% of school leavers who want to do science and maths at university. “Cambridge pure mathematicians are still the crème de la crème,” she says. “But I’m interested in the vast majority of schoolchildren, every single girl and boy in the country, all of whom deserve a good mathematical education for its own sake.” Hoyles taught maths in London for several years before moving into teacher education, eventually fronting her own TV show in the 1980s featuring maths problem solving. She talks of the “infinite beauty” of mathematics for its own sake. She believes that maths is not only fun but crucial for mental development. Hoyles was chosen by Charles Clarke, when he was education secretary, as chief government adviser for mathematics.

When I spoke to Clarke recently he dismissed the “problem” of modularisation: “I don’t think modularisation or the curriculum are at fault, but I grant that demoralisation of teachers is an issue. The problem, it seems to me, is one of enthusiasm, and a need for teachers to come together in groups to swap ideas and generate creativity among themselves. This could be done on a local basis. I think that industry and commerce could also make a contribution. Instead of complaining about standards, they should take a direct hand in supporting maths and science in schools.”

Hoyles refuses to accept that things are getting worse. “Just remember,” she says, “that when I was at school in the early 1960s, only 5% of school leavers went to university. Now it’s 40%.” But she is nevertheless passionate about the need to make maths “normal”, to eradicate its reputation as difficult and boring. “What’s wrong with us? I asked the presenter on a TV show recently to multiply seven by seven, and he freaked out with sheer panic!” Hoyles believes early success at maths is indicative of both numeracy and literacy skills later in education. “Research shows children who achieve a good standard of maths by the age of seven do better later, not only in maths but in literacy too.” Her strategy has involved the creation of initiatives such as the Millennium Mathematics Project and its internet-based maths club Nrich (www.nrich.maths.org), which anyone can join at their own competence level if they have a laptop: the current programme reveals how biscuit decorations involve mathematical problems; at a higher level it teaches “attractive” approaches to Pythaghoras’ theorem and 3D.

Jennifer Piggott, a former maths teacher in north London, current leader of Nrich, is critical of the modular approaches that fail to

promote “fluency” in maths. “It’s no use grasping a particular topic or equation only to then neglect it. You need to do it over and over again. It’s like learning a language… You don’t learn a bit of Spanish grammar then not use it. You have to use it or lose it.”

Cambridge University’s director of admissions, Dr Geoff Parks, endorses the “fluency” problem as the main setback for the current generation of science and engineering entrants. “They’re just too slow. That’s why we have to spend a lot of time priming up their maths in the first and second years. That’s why most science courses are now four years instead of three.” He adds that there is a significant dropout rate from physics, often a result of difficulties with maths, into other subjects.

Michael Reiss, who has returned after the Royal Society creationist row to the Institute of Education as professor of natural sciences, accepts most of the criticisms levelled at science undergraduates. But he rejects the view that everything is in decline. “Take biology, a hugely important subject nowadays: years ago we used to just label things like the ear — it was rigid and static; today the subject is amazingly dynamic and enjoys all the advances in genetics and molecular biology. It’s hugely popular and successful.” Reiss insists that it’s no bad thing to catch up with maths at university: “Most of them achieve this successfully.” Nor is he depressed by the numbers of university students who give up physics in the second and third years, daunted by the mathematical difficulty of the subject. “These students with a basis in physics are making fantastic contributions in other areas — technology, social sciences, medicine, history and philosophy of science.” Reiss is similarly dismissive of the view that Britain’s universities are slipping, according to the Times Higher Education magazine, in the “world’s best 200” league tables. “It’s not surprising that Britain has gone down a bit, when you compare the relative budgets of US and British universities. But 29 of Britain’s universities are still in the top 200, a prodigious achievement.”

England’s Higher Education Funding Council (HEFCE), moreover, claims the number of students studying maths, physics, chemistry and engineering is actually on the increase after a period of decline. The number of students doing maths at university rose last year by 8.1% on 2007, chemistry by 4.4% and physics by 3.3%. The turnaround comes after a decline between 2002 and 2006, when 38 university science departments closed in the UK and the number of pupils studying science subjects at A-level plummeted.

The HEFCE claims the reversal is due to a £350m government cash injection channelled to schools, universities and education organisations to stimulate enthusiasm. A crucial focus has been mathematics, regarded as the basis of all the sciences, and peculiarly problematic for the British, according to Celia Hoyles, who has been appointed director of the recently established National Centre for Excellence in the Teaching of Mathematics. “Sadly,” she says, “many people have bad experiences at school that leave them feeling maths is a cold, impersonal set of procedures with little relevance or meaning.” She has spent her career trying to understand this British block. “While children learn how to do algebra and calculations, we ought also to show them the power and beauty of the mathematical perspective. If you look at life through mathematical spectacles, new relationships unfold: spirals on shells, the way water ripples in streams, amazing symmetries in geometry. Raw disconnected facts are not enough.”

Science teachers at every level agree that while maths is the essential underpinning skill, teaching is often uninspiring and irrelevant. A step forward, in the view of many educationists, is the recent decision by the children’s secretary, Ed Balls, to drop the stage-3 Sats tests, which were demoralising many teachers. Celia Hoyles believes, however, that teachers have got to get across an appreciation of the relevance of maths for the 21st century: “We live together in a mathematical world of structure, pattern, sense. It underpins all the sciences, the social sciences and much more… it underpins your laptop, your mobile, your Oyster card, your credit card, your time management, any medication you take and its dosage, your likelihood of living long enough to know your grandchildren: this all absolutely depends on mathematical understanding somewhere along the line.”

As Britain enters its worst recession in decades, while facing a gamut of dire new challenges — from global warming, to water

shortages, to energy crises, to financial crunches — fluency in maths, as a prelude to grasping the underlying workings of science and technology, could be the best investment we could make as individuals, as families and as a nation. It's an investment that is already being made on a vast scale in India and China, where students in maths and science are currently graduating in their hundreds of thousands.

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