



House of Commons

Children, Schools and Families  
Committee

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# Teaching of STEM subjects

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**Oral and written evidence**

*Ordered by The House of Commons  
to be printed 3 and 10 February 2010*

## **The Children, Schools and Families Committee**

The Children, Schools and Families Committee is appointed by the House of Commons to examine the expenditure, administration and policy of the Department for Children, Schools and Families and its associated public bodies.

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## Taken before the Children, Schools and Families Committee

on Wednesday 3 February 2010

Members present:

Mr Barry Sheerman (Chairman)

Annette Brooke  
Ms Karen Buck  
Mr David Chaytor  
Paul Holmes

Mr Andrew Pelling  
Helen Southworth  
Mr Edward Timpson

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### Memorandum submitted by the Institute of Physics

#### INTRODUCTION

This paper constitutes an addendum to the evidence we provided to the CSF Committee on 30 January 2009.<sup>1</sup> It both offers an update to that paper, together with some key suggestions on how the situation might be improved.

#### BACKGROUND AND RECENT DEVELOPMENTS

- NEFR's 2006 school survey reported science specialist teachers in the proportions: biology 44%, chemistry 25% and physics 19%. The Government's physics target of 22% by 2014 looks increasingly unlikely to be achieved.
- Recent reports from the University of Buckingham indicate that in almost 1/5 of secondary schools, physics teaching is carried out by teachers with no post A-level experience of the subject. DCSF data show that as many as 500 schools have no pupils at all progressing to A-level physics.
- The commonly agreed figure for the number of new physics ITT recruits to begin to reverse the long-term trend is 750 per annum; the long term average annual recruitment is around 400. Approximately one third of physics specialist teachers are expected to retire in the next 10 years.
- The Institute welcomes the imminent School Workforce Census, which will yield vital data on attrition rates, which have been difficult to determine historically.
- In partnership with the National Science Learning Centres, the Institute has established a network of physics centres across England in the *Stimulating Physics Network* (SPN), funded by the DCSF. An important part of this project is the model for taking support into schools to work with whole departments of non-specialist physics teachers, which has been shown to be more successful than other approaches offered to date.
- Supported by the Gatsby Trust, the Institute has also embarked on the *MITRE* project, working with ITT providers and physics departments to improve the marketing of teaching to physics and physics-related graduates. This work sits alongside the work we are doing to provide mentoring support to participants on the *Physics Enhancement Programme (PEP)* and the *Science Additional Specialism Programme (SASP)*.

#### RECOMMENDATIONS AND SUGGESTIONS

##### *Recruitment and ITT*

1. The TDA should take steps to encourage HEIs to market their courses more effectively and to increase their capacity. There should be a progressive move to setting recruitment targets for each of the sciences.
2. We support the suggestion by the Conservative Party that the Government should consider repaying the student loans for teachers in shortage subjects so long as they remain in the profession. Such a move would also improve retention. We are also sympathetic to the idea of raising the status of the profession, although we are less convinced by the blank restriction to the higher degree classes.
3. ITT tutors are generally former teachers with no training in research. However, on appointment, they enter a university environment where research is highly valued. While there are considerable benefits in having a sound research base for ITT, it is not clear that this model is best for all ITT tutors and there is evidence that many of them find the research element difficult and time-consuming. The TDA should explore other models that do not have this requirement to carry out original research.

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<sup>1</sup> See the Fourth Report from the Children, Schools and Families Committee, Session 2009–10, *Training of Teachers*, HC 275-II, Ev 292

4. Placements are a major problem for many ITT providers and may inhibit recruitment in some cases. There should be an investigation of the feasibility of *requiring* schools, or groups of schools, to take trainee teachers. Strategic planning for increasing the capacity in the placement should be undertaken as a matter of urgency.

5. The ITT application system needs streamlining to avoid unnecessary wastage and delay. In particular, there needs to be greater accountability within ITT institutions and greater transparency within the GTTR system. It would be helpful to have an unambiguous and categorical figure for the total number of entrants in each subject area, for example.

6. A quarter of all physics graduates who enter teaching choose mathematics as their specialist subject. These teachers obviously could teach physics but usually do not simply because it is hard to do so within school management structures. With an appropriately expanded PGCE (see below) with more linkage between training and teaching, there is no reason why such arrangements should not be encouraged.

#### *Retention and staff development*

7. Mentoring programmes can help retention but we have serious reservations about the current national pilot scheme operated by the TDA. We recommend a more pro-active scheme, such as the one employed within our PEP project.

8. The Institute believes that the current one-year PGCE provides neither sufficient training in subject knowledge and pedagogy nor support for NQTs on their first appointment. We suggest an extension of the PGCE to become a three or even five year programme, most of which is undertaken during the NQT years. Such an approach would give more confidence and support to the NQTs as well as providing the pedagogical support where and when it is most needed.

9. If CPD is to become a sustainable part of a science teacher's career, there needs to be either some sort of professional requirement or an incentive. It is possible that CPD could be linked with the development of an "expert teacher" status, possibly in partnership with the relevant learned societies, which would also make a bridge to the latest developments in the subject.

#### *The science curriculum*

10. To retain specialist physics teachers, it is essential to retain physics as a subject with a specific identity from *at least* GGSE onwards. It is often stated that the curriculum needs to stimulate pupils; in fact, it is probably more accurate that the curriculum needs to stimulate teachers.

#### *Co-ordination of initiatives that relate to STEM teaching*

11. There have been several attempts to map out the various initiatives and to make them coherent, with rather limited success. The problem is that, for every local scheme of undoubted quality, there are others with rather less success. The recent tendency to give almost every regional and local body an obligation to promote STEM has not improved the situation and should be reviewed.

12. In paragraph 7 above, we suggest an extended PGCE and in the following paragraph a possible route to becoming classified as an expert teacher. If these two schemes were adopted and made coherent, much of the need for coherence would disappear.

Peter Main  
Director, Education and Science

February 2010

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### **Memorandum submitted by Dr John Oversby**

#### **1. FACTORS IMPACTING ON/HOW TO IMPROVE RECRUITMENT AND RETENTION TO STEM TEACHER TRAINING AND THE STEM TEACHING WORKFORCE**

Applications to STEM teacher training are probably adequate in total numbers but many applicants are rejected in the selection procedure. The requirement to teach across the sciences (TDA) is a high hurdle to overcome. Since much of the lower secondary school science teaching is carried out by those qualified in life sciences, it is important firstly that they have confident and secure subject knowledge across the sciences, deeper and richer than that they have to teach to their pupils and students. Generally, such graduates have avoided the physical sciences post-16, especially physics, mainly because of a lack of interest and confidence. A similar position is held by physics and engineering graduates, who have often avoided both chemistry and life sciences. The IoP suggest that physics graduates are often very strong in their opinion that they should only teach physics. In addition, physics and engineering graduates often have a strong commitment to

mathematics teaching, leading to 25% of them teaching only mathematics in schools. I believe that graduates have the intellectual ability to learn across the sciences but the issue is mainly one of motivation, in my experience of interviewing 1200 applicants to PGCE and GTP courses. The all-science requirement is also a significant reason why some of those in training leave. They were faced with the reality of teaching outside their zone of confidence, and hated it. Recruitment has been positively affected by the training bursaries, as TDA evidence shows. However, the bursaries represent only a minimum and it is not sufficient to attract some career changers, and it is a significant cause for those leaving during training, not least because the PGCE course is so demanding in time and commitment that trainees can not supplement their income by part time employment. A final reason why recruitment is affected, and why retention is often difficult is concerned with the values of the applicants and trainees. They arrive with a view that teaching is concerned with transmission, lecturing, and this is not challenged by the methodologies of their undergraduate courses. Faced with the need for interactive and engaging methods for the adolescents in their care, they are often unprepared for this in their previous science experience at university, and they find it too difficult to adapt. In short, perhaps university courses attract more of a certain personality type, focused more on ideas than people, and working with things rather than in establishing human relationships. This may underlie a frequent comment “I only want to teach those who wish to learn” which in discussion translates to wanting to transmit knowledge to those who are good receivers, and not good in discussion.

## 2. THE DEVELOPMENT NEEDS OF STEM TEACHERS

The major need for science teachers is in pedagogy, not in subject knowledge. My comments above about methodologies are concerned mostly with inspiring, engaging and supporting learners. STEM teachers have to develop interactive methods, and to provide more opportunities for their pupils/students for independent learning. In practical work, the pedagogy of enquiry methods at school is quite novel to most graduate scientists so that they need much help in this area, not least because it is high quality practical enquiry activity that is most effective in engaging and inspiring their pupils/students. It is also very challenging to adopt this method in large classes in the 11–16 age range, which is why CPD in this aspect needs more attention. Much of the existing practical work is uninspiring, as was recorded in this Committee’s inquiry in 2002. “Investigations” continue to be routine and limited in range and challenge. A reason for this uninspiring practical work may be that the teachers are generally not confident, and sometimes not safe, outside their degree specialism. It is my experience that subject knowledge can be developed once the teachers are confident with the pedagogies I have described. In this case, independent learning and short subject content courses may be more appropriate, although my experience with my EU History and Philosophy of Science project suggests that this project’s approach could be a stimulating and effective route for developing rich and deep subject knowledge, and knowledge about the Nature of Science. A further barrier to effective CPD is an increasing reluctance by Head Teachers to release teachers, and the latest guidance on “rarely cover” has further restricted the opportunities for teachers to take part in CPD during school term time.

## 3. THE SCIENCE CURRICULUM/PUPILS’ ACCESS TO SCIENCE.

The science curriculum remains dominated by traditional content knowledge, to the detriment of other inputs such as enquiry, history and philosophy of science (to counterbalance the present weak interpretation of How Science Works), argumentation, and debates/discussions on controversial issues. The Triple Science movement has entrenched this domination, with the best of intentions, but it is clear from international studies such as the Relevance of Science Education project that this kind of science engages only a small proportion of the population. There are still many strong views, from the learned scientific societies for example, that suggest that piling on more content is the way to improve STEM recruitment. While there is still insufficient evidence to substantiate or refute these views, it runs contrary to the need for science for the rest of the learners, many of whom steadfastly reject such a diet as being irrelevant. Even the Triple Science movement is beset by problems such as the continuing shortage of (good) physics teachers. I would recommend a radical review of compulsory school science, that is science to 16+, that focuses less on traditional knowledge, but I recognise that this will be unacceptable to the powerful forces I have mentioned. In any case, access to science is filtered by the availability of high quality science teachers.

*February 2010*

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*Witnesses:* **Professor Derek Bell**, Head of Education, Wellcome Trust, **Professor Sir John Holman**, National STEM Director, DCSF and Director, National Science Learning Centre, **Professor Peter Main**, Director, Education and Science, Institute of Physics, **Dr John Oversby**,<sup>1</sup> History and Philosophy for Science Teaching Project (Reading University), Association for Science Education, and **David Perks**, Head of Physics, Graveney School, Tooting, gave evidence.

**Chairman:** I welcome today's witnesses. We are very impressed by the amount of talent in front of us. We have Professor Sir John Holman. Congratulations, John, on your knighthood, which I think was in the new year's honours this year. We also have Professor Peter Main, Dr John Oversby, David Perks and Professor Derek Bell. This may be harder on you, Sir John, but we tend to revert to first names in the Committee just for a level of informality. Is Sir John all right, rather than your full title?

**Professor Holman:** John is absolutely fine.

**Q1 Chairman:** Good. That eases the transition to a more congenial atmosphere. As I said outside, this session is not an inquisition from our point of view—we'll call you back when we want an inquisition. Karen immediately pointed out that we have no female physicists here this morning. That is one thing you might want to address when we get to Karen's questioning. First, we will give you a chance to say quickly, in a nutshell, what you think about where we are with the science, technology, engineering and maths subjects in English education at the moment. One reason why this Committee has not looked at this issue for a very long time is that we have tended historically to allow the Science and Technology Committee to concentrate on this area because we had such a large remit anyway, but so much is happening in the STEM area and many of the challenges have not changed much over the years, so we thought we would dip into this and perhaps link it to other inquiries we are doing. On Monday, we were looking at the gifted and talented programme. In a week or so, we'll be looking at education outside the classroom. Sir John, I shall start with you. Where are we on this? There have been loads of initiatives and new programmes. I visited your fantastic centre at York and I've now visited two of the regional centres for science. Is this cracking it?

**Professor Holman:** Well, just thinking first about what the problem is, it has been seen in most ways as a quantity problem. Sciences and mathematics were seen as not popular among young people, so the mission has been more than anything about trying to get more young people continuing with science and mathematics past the age when they can drop them. If that is the mission, the kind of indicators you would look at would be, for example, numbers doing A-level physics, A-level sciences and A-level mathematics. In that sense, we've turned a corner, but we have a long way to go. That would be my summary. Numbers taking A-level physics have just begun to turn up after a 30-year decline, but there is still a long, long way to go and the rate of growth is

quite small. Mathematics is growing very strongly and that's great. Chemistry is not bad and biology has never really been under threat. We've turned a corner, but there is a long, long way to go and the need for it is greater than it has ever been. Because of the state that we're in socially and economically, the need for quantitatively skilled and analytical individuals going through into the work force is greater than it has ever been, and the rewards to the people who have those qualifications will be greater than they've ever been. The need has intensified and the problem is still a major one, but we're travelling in the right direction.

**Professor Main:** I agree with the final sentence. We're travelling in the right direction, but that there are a few steps forward, a few steps back. One of the most positive things is the way in which STEM education over the past few years has been taken very seriously—John's appointment, among other things. The fact that senior people in industry and politics have said that we need more scientists and engineers has been very positive and is part of the reason for the upturn. John alluded to the shortage of physics teachers. That is very serious, and possibly the most serious of all the problems within the STEM community. There are many statistics that we can bandy around. We have identified 500 schools that do not send any students to take physics A-level. A substantial percentage of schools and colleges that do A-levels are not running physics A-level. A couple of other issues have emerged. Over the past few years there has been a fairly rapid and incoherent curriculum change. Lots of initiatives are in what seems to be a random order, and some that have not been piloted properly have had some effects in the classroom. We must look at the drivers within the education system in the schools that are forcing behaviour such as league tables, university entrants and the behaviour of the awarding bodies. Many drivers seem to be pushing people away from the STEM areas, and perhaps some of those things still need to be addressed.

**Q2 Chairman:** How do we compare internationally? I have not read systematically on it, but I get the picture that what we used to call the western industrialised world shares the problem.

**Professor Main:** That's right. There is a correlation between participation in physics and average temperature.

**Chairman:** Really?

**Professor Main:** There is the problem with physics in the northern developed parts of Europe. It is particularly true of the gender issues.

**Q3 Chairman:** I spent some time at Cornell university and it said that if it did not have students from China and other places, it would not fill its places in physics. Is it a problem in Europe and North America?

<sup>1</sup> *Note by witness:* Please note an article on neuroscience-relevant to Qq 25–29. Harlen W (2010) "What do studies of the brain tell us about learning?" *Education in Science* (February 2010) 28–29 ASE, Hatfield.

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**Professor Holman:** The disenchantment and disinterest in science is a problem of developed countries. It is in complete contrast to developing countries.

**Q4 Chairman:** We will perhaps dig a little deeper on that. John, you have some interesting things going on at Reading.

**Dr Oversby:** It might not be too helpful to talk about science because the sciences are not the same and they bring valuable but different perspectives to what is going on. The plethora of initiatives indicates great concern, which is focused a lot on future career scientists. We accept that; it is one of the major issues. We lack a lot of evidence about what is going on. For example, we collect evidence through the Department for Children, Schools and Families on teachers' subject knowledge, largely through their degrees. That is a long time ago for me, as it is for many teachers, so we do not have a lot of up-to-date evidence about what teachers know and what they've learnt after their training courses. We do not have a lot of evidence about what the graduate physicist, the graduate chemist and the graduate biologist think about teaching. We have anecdotal evidence and, if we are to have good policy development, I would like a lot more focus on its being based on systematic and rigorous evidence.

**Q5 Chairman:** I am commissioned to suggest that the Smithers and Robinson inquiry into the training of teachers and science teaching was a remarkable contribution.

**Dr Oversby:** Yes, I was part of that—as a victim. I was interviewed. I will not tell you about which of the bits they did not include because it might be embarrassing. If you ask me more clearly later on, I might say something about it. We are focused. Ofsted focuses on the degrees of the people coming in—50% of those people coming in are mature students, so how much have they learnt from their degrees? One of the political parties says, “We shouldn't have people who have certain classes of degrees”, and they are focusing on that too, no matter how long ago those degrees were earned or what people have shown about developing their personal subject knowledge since. That is part of the problem. We make a big assumption about whether people have degrees in a particular subject and how that is related to teaching in school. Sometimes the match between the content of the degree and teaching in lower secondary school is not as great as it might have been. Partly that is due to changes and developments in the curriculum. I want to admit—and praise—changes in the curriculum, but it is really hard for people who have a passion and enthusiasm for their particular degree subject then to go and say, very easily, that they want to do other things. I think that is why I am focused so much more on what the qualities are of the teachers we've got, in particular in handling some of the new initiatives. We can have new initiatives, but if we do not do the appropriate training for those people, then we are just making them feel guilty about the

fact that they cannot handle it. I think that's another big problem we've got—by having so many initiatives coming in and people saying, “We can't do it.” It is not surprising that many of them are then saying, “I don't want to stay any more.”

**Q6 Chairman:** Thank you for that, John. David, you are a real head of department in a real school.

**David Perks:** Yes. On that, though, my perspective is a bit broader in a sense—the way I come to this—and I slightly disagree with something that John said. I do not think this is a problem of young people. I do not think that young people are not interested in science. If we start from that premise, we are making a fatal mistake. It is almost common sense—for young people, teenagers, etc, getting the chance to ask questions that, say, studying physics or the other sciences allows you to ask about themselves, the world, the universe, etc, is one of the most engaging things that they can do. Certain answers should be bread and butter to a science teacher. If a kid says to you, “Why do I have to do this? I am never going to use it again in my life”, that is the death question for a teacher, but it is the right question for a child to ask of any teacher of any subject. This should be your bread-and-butter response: “This is why”; “This is why I am passionate about what I am doing”; or “This is why it is important”. It's as simple as that. Once you have done that, the engagement is there. It is not the case that the kids are bored with science—that is not good enough. It is much more the case that we have lost confidence that we can deliver science in an interesting and appropriate way. Once you go down the path of starting to say that academic science is dry, dull and boring, then you give it up. I think the question is entirely different. If you have the confidence to go about your subject and do the dry, dull and boring—in physics, Ohm's law, which frightens people—then you will actually win the kids around, and you will get recruits to the quest to understand the world around them and to a belief in science and the power of science. Then they may well choose to take the subject up. But they cannot do that unless you believe that it is worth while. This is a massive mistake that we have made. The way that works itself out in the curriculum is, I am afraid to say, in the essence of all reforms in the science curriculum over the past 10 or 15 years. We have reduced content and replaced it with something else, whether nominal skills or some kind of appeal to interest and making something relevant by throwing in controversial ideas, such as “Is nuclear power good or bad?” or “Is genetic engineering dangerous?” It is an attempt to reinvigorate an interest in something, but we do not need to do that in the first place. The end result is to dilute the subjects themselves, if not to avoid calling them subjects in the first place, and devalue the very thing that you want teachers to bring into the classroom—their passion for their subject. It is no wonder teachers find it hard, having done a degree in, say, physics, to then find out that they are not really teaching physics when they go into the classroom.

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That mistake is being made again and again every time curriculum changes are brought in. It is one thing that we need to stop and think about very seriously if we are to redress the balance. A further point is that the plethora of qualifications—just up to 16—is now so wide that it is difficult to know what is going on. So the notion of choice, which was thrown in in the last GCSE reforms, means there are now so many routes through GCSEs that no one knows how to understand it. Worse still, the vast majority of state schools are now eagerly eyeing up BTECs—vocational qualification equivalents to GCSEs—as being far more beneficial for them, because they are easier in terms of grade equivalents. Therefore, if you look at the figures for separate sciences, you might see that there is a rise in separate sciences over the recent period—a moderate rise—but the rise in BTECs is massive. That means that the way in which young people are being taught science, up to GCSE, has radically changed, and it is now no longer an academic subject for the vast majority of young people. My concern is that we need really to say that we have a strong belief in the validity of an academic and scientific base in knowledge for all young people, not just one or two.

**Q7 Chairman:** Thank you for that, David. I had a total flashback to the school laboratory when you mentioned Ohm's law. I could see the laboratory and myself in it. Ohm's law brought it all back. Derek, you work with the Wellcome Foundation, which puts so much effort and resource into this area. You have heard the four other contributors. Where are you coming from on this?

**Professor Bell:** First of all, there is not much left to say. All the issues have been raised. That is part of the problem and also part of the solution. There are different perspectives on this. One of the dangers that we fall into is that we start to create these things as black and white, and that is not actually the case. It is about balance. It is also about coherence. One of the problems—Peter touched on this, I think—is that very often when we have looked at science education or even education more generally, we have tended to look at particular aspects of it rather than standing back and looking at how that fits and what the implications are. If you look back on some of the developments in science education, there is some coherence as to the way it has been going, because some of the issues have been raised many years ago, and we have tried to find solutions. But to some extent, that coherence is not obvious and it is not clear to everybody, so I think we have to look at that. Also, I think young people are interested in science, and there is some evidence to reflect that. Firmer evidence is starting to come out, which hopefully is a result of some of the activities that have been going on over the last four or five years, led by John and others. So I think they are interested. To that extent, I agree with David. Part of our job is to bring that interest out and ignite it for them, rather than just say, "They're bored by it." Kids at 14 or 15 are bored by most things. So let's not beat ourselves up too much. Let's do something about it. The other issue

that always gets into this debate—it is something that we really have to get back to and look at very carefully—is the balance between factual content, if I can put it at that extreme, and the skills and processes. Science is not either/or; it is both. You need the factual knowledge and you need the processes, and you build on that knowledge to get new knowledge. There is an interesting paradox. Generally speaking, when I ask scientists how they define science, they talk about exploration, discovery and looking for new things. When you talk about what happens in school—although this is a bit stereotypical—it tends to be, "These are the answers; these are the facts that you have to know," so a lot of the excitement is lost. It is about putting that balance right so that young people get the excitement of science and the inspiration—that is why we are all sitting here, because that is what we enjoyed—as well as building up the blocks of knowledge they need to understand and appreciate fully what is going forward.

**Chairman:** Right. I think we are thoroughly warmed up now. David, over to you to ask about the initial teacher training and recruitment.

**Q8 Mr Chaytor:** I would like to start by going back to the question of physics undergraduates and those doing physics A-level. John, in your opening statement, you said there had been a 30-year decline in the numbers taking physics A-level. What is the scale of that decline? It is presumably reflected in the number of people choosing physics degrees.

**Professor Holman:** Yes, although Peter might be able to give a more precise response. The numbers taking A-level physics are about 29,000 a year at the moment. That has declined from a high point of probably more than 40,000 in the 1980s. This number is just beginning to tick up again, and it is interesting to ask what number we should be looking at. We look at the gross numbers—there is a rationale for doing that—but it is also interesting to look at is the percentage of the cohort that makes the choice to study A-level physics. The participation of young people in A-levels has gone up strongly and continues to do so, but that, in a sense, is another story. There is a long-term decline. The number is now at 29,000, and DCSF has set itself a target to get it back up to 35,000 by 2014. It will be a big struggle to get to that number. It could be solved almost instantly if we could address one persistent underlying problem in physics: its lack of appeal to girls. At the moment, about 22% of A-level physics candidates are girls, and it has been stuck at that for as long as I have been looking at the statistics. If that could be turned round, we would no longer have a problem with the number of A-level physics students that this country produces. You are quite right to say that that in turn feeds through to degree courses, which has been, and continues to be, a cause of concern. That has resulted, as you know, in the closure of physics departments in some universities. That, too, is a trend that has been reversed. Numbers

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applying to take physics, chemistry and other STEM degrees at university are now going up, as are A-level numbers, reasonably strongly.

**Chairman:** Peter wants to come in on this.

**Professor Main:** Just on the statistics. John is right. In the late 1980s, we were running at about 45,000 doing A-level physics and we are now below 30,000. The onset of the decline correlates—I am not going to say causes; I am too much of a scientist for that—with the introduction of GCSE double science. It is an interesting observation, which you can find in the latest of the Smithers and Robinson reports, that the numbers for O-level physics before GCSE double science was introduced were increasing year in, year out—mostly monotonically increasing—at a time when people were allowed not to choose to do physics at the age of 16. On the degree choices, a rather interesting phenomenon has happened. The A-level numbers collapsed, and John is absolutely right that lots of physics departments closed—from 72 to 47 over the same period, from when the RAE was introduced in the higher education sector. However, the number of people taking physics degrees has actually not changed very much at all. It has not expanded at a time when there has been major expansion in the HE participation rate, but stayed at roughly 3,000, although it has bobbed around, as you would expect. It has gone up in each of the past three or four years, however, and we probably have more physics students in our universities now than we have ever had. The curious effect is that the number of people doing physics at degree level—the hard core, if you like—has always stayed there, and it is others who have dropped out at A-level. That has had a rather stronger effect at university level on the subjects aligned with physics—engineering, material science and so on.

**Q9 Mr Chaytor:** So we can presumably conclude that of the 45,000 students taking the A-level in the late 1980s, many were not terribly enthusiastic or did not do terribly well, which was why they did not progress to do physics degrees. There is a discrepancy between the numbers taking A-levels over 30 years and those taking degrees.

**Professor Main:** No, I think you have to look at physics slightly differently in schools and in universities. Physics in schools—a bit like maths but not quite, as maths is so general—is an underpinning subject, and so if you want to go into any engineering discipline or material science, or even things such as medicine if you are really honest, physics is a good subject to have. If you look, as we did some years ago when we did our undergraduate physics inquiry, at what the people did after physics A-level, almost all of them went on to do STEM subjects. Whether or not you do physics A-level is probably the biggest correlator as to whether you will then go on to study a STEM subject at university. I do not think there was a problem then. My interpretation is that there is a certain sort of person, of which I am one—you might have your own prejudices about them—who really enjoys and is intrigued by physics: the big questions, astronomy,

particle physics and all those sorts of things. That sort of person has always been there and is still there. The people who perhaps see physics in a different way and are not driven by those things are going to go on to the more applied areas in STEM, and they are the ones who appear to be dropping out.

**Chairman:** John, and then on to the other John.

**Professor Holman:** Could I just add one thing about the point about the numbers doing degrees in physics remaining constant. I can comment from the perspective of chemistry, which is in a similar position. It is true that, despite department closures, the numbers have not gone through such big swings at university as they did at A-level in chemistry, but that masks another effect, which is that universities drop their entry requirements so that they fill their places. At the University of York, for example, 10 years ago we would have been asking for a B and two Cs to study chemistry, because we were terribly worried about the numbers, and now we ask, I think, for two As and a B. In other words, the market is shifting towards an excess supply of applicants, and the number of places, while it does expand, does not expand at the same rate as the increase in supply. The numbers doing degrees in chemistry might not be expanding dramatically, but the qualifications of the people who come, at least from our experience at York, which I know is repeated elsewhere, do change. One final point about this, which is really quite important, is that when a chemistry department feels that it is on the back foot and has to try to increase its appeal by lowering its entry requirements, one thing that it would tend to do would be not to insist on A-level mathematics. A-level mathematics is very important for the study of chemistry, and even more so for the study of physics, and yet departments have been saying, “We’ll take you even if you haven’t got A-level mathematics”, simply because they need the people. That has led to a situation in which university departments have to take remedial steps to teach mathematics because the candidates do not have A-level mathematics. There is an opportunity here, with the increasing popularity of STEM subjects and the big growth in A-level mathematics, for our departments to win that ground back.

**Chairman:** John has been very patient.

**Dr Oversby:** I am always patient. I should start off by saying that I am an officer for the Royal Society of Chemistry. I meet lots and lots of chemists, as I did last night, and many people who have spent their careers in chemistry. You might like to know that, for a great change, the average age of our group from the local committee was about 30 yesterday, rather than 65. We have been working on getting more young people involved in taking action within the Royal Society of Chemistry in my section in Thames Valley. Nevertheless, the number of careers that there are in pure chemistry has certainly declined, and that has had an impact on the number of people who would like to study chemistry at university. There are other reasons why people are studying chemistry, as John has already mentioned, and that has mitigated some of the impact of the careers in the

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pure subject. One of the big impacts, from my knowledge, is the great increase in the number of people who are studying medicine—it has blossomed. It is taking many of our more able students; and whether they are more able in chemistry or physics, they are nevertheless taking A-levels in those subjects. Medicine, with its big increase over the past 10 years or so, is mopping up a lot of the students who are taking A-levels. If you want to look at the overall picture, go back to what I said before. We need to have more hard evidence about why people are choosing these things before we can try to make decisions. I think we have lots of anecdotal evidence, but we don't have very good personal evidence about why people are choosing things. We have the overall subject numbers and the overall decisions that people are making in terms of who is choosing this, but we don't know why people are doing them, and I think we need to have more about that. At Reading this morning, I talked to a colleague who is a professor of chemistry at another university. He told me about the university courses being very highly "mathematised"—I might be inventing that word, but we understand what it means. That is in chemistry, and we know that physics is much more in that direction than the other ones. The impact of the understanding of mathematics and, perhaps more than that, interest and motivation, are affecting the situation. I want to finish on one final point about Reading. I am not in the physics department or the science faculties; I am in the institute of education, as you might know. Reading's physics department is closing this year, and I want to make the point that there are more physics graduates and lecturers who are working at Reading outside physics—for example in meteorology, which is an outstanding department at Reading—than within physics. We are still going to have large amounts of physics taught at Reading.

**Chairman:** Thank you.

**Q10 Mr Chaytor:** Whatever the trend in numbers or in the quality of people recruited to physics and chemistry degrees, the fact is that it is difficult to persuade them to go into initial teacher training. I want to move on to why this is, what universities are doing about it and why there seems to be so little contact between science and education departments in making teaching a more attractive career for good undergraduates with good science degrees.

**Chairman:** I think we are neglecting other witnesses. Anybody want to start?

**Professor Bell:** The issue of choice is something that runs through this whole conversation, in the sense that at one point, the number of subjects you could do at GSCE, or O-levels in the old days, was relatively limited; that has expanded. David touched on a whole range of qualifications. You take it up to a degree level, universities have problems recruiting to subject areas, and they change the courses and try to make them more attractive. I think you then take that into the situation. The attraction for people to

go into other careers beyond teaching also makes a difference at a general level, and I think that's one of the things we've got to work on.

**David Perks:** I think, in terms of teacher recruitment, it's quite a difficult problem to get your head around. Let's put it this way: if you don't value the expertise of the teachers you've got, you're hardly likely to keep the new ones around. In that sense, you can understand it like this: teachers don't grow, they're made. If you're a young teacher and you come to a new school and want to learn your craft, you're going to lean on somebody and there has to be at least one person there you can lean on. That's in terms of subject knowledge as well as mastering the craft. On the point about subject knowledge, there is a mistake about this and it's already been mentioned. I'm talking about the Gove plea for elite teachers in the profession. The idea is almost that they just come in, ready-made. Even the subject knowledge that you bring in isn't good enough if you have a good degree, because you read your degree and you absorbed that knowledge yourself. That doesn't mean you can replicate it to somebody else. You have to re-learn your own subject to be able to teach it. It's always the same. People realise this and think, "Oh my gosh, I can't explain this! I have to go away and think it out because I have to make some little mind understand it, and they have questions I haven't thought of." So you're re-learning your subject. That's a craft and a set of skills that you can only get on the job, so you need encouragement and fostering and someone there to lean on. That's experience—you need experience. The problem is that the way the teaching profession is organised at the moment militates against that consistently. It's always the idea that you fast-track people in, zoom them in, and that's it—they're in management before you know it, and so on. That's the route that new teachers, if they're any good, take. They go into management; they don't stay in the classroom. Subject knowledge is right down the bottom of the agenda of what is preferred, what is prioritised, in terms of development for young teachers. That's the problem you have.

**Chairman:** The problem I'm going to have as Chair is curbing your enthusiasm for your answers! Peter?

**Professor Main:** To begin with, on the point about contact between physics departments and education departments, my background is as a physicist. I spent 20-odd years as a professional physicist at Nottingham and we had an education department at Nottingham. It was training physics teachers and we had almost no contact with it. We have seen this around the country. In fact, we have a project at the moment, funded by the Gatsby Foundation, on this very issue—trying to build greater links between physics departments and schools of education. We believe, and we have more than anecdotal evidence, that the marketing of teacher training could be improved considerably, particularly in the area of physics. One of the changes that the Training and Development Agency for Schools has just brought in, which we wholeheartedly support, will involve the setting of separate targets for physics, chemistry

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and biology, instead of setting targets for science. We think this is a really important step, because it's no good talking about a specialist science teacher; you have to talk about specialist physicists, specialist chemists and specialist biologists. That is a very important step, but we do think—I won't say much about this now—a lot can be done within teacher training establishments. There are issues about the work load there. For example, they are assessed by the research assessment exercise and by Ofsted, unlike most of their university contemporaries. In addition, we know that of the people who go into teacher training, most of them are ex-school teachers and they are then expected to do international-level research in relation to the RAE. That is a really big ask and we wonder whether the model for teacher training could be looked at a little more creatively in that direction. Another issue that I know from my days as a physics tutor, and which is important, is that many physicists do not want to go into physics teaching because they think they will have to teach chemistry and biology. Most physicists would be perfectly happy to teach mathematics along with physics. In fact, a quarter of the physics graduates who go into teaching go in to teach mathematics purely, as opposed to teaching physics. These are people we're losing. We've looked into the reasons why this is occurring and it has nothing much to do with teacher training, because you can train to be a physics and maths teacher. It seems to have more to do with school structures. The management structures within schools don't really allow people to teach physics alongside mathematics. Again, that seems to be a rather difficult problem. I'll finish with just a few words on retention. We need to know more about the retention of teachers. Very little is known. If you ask the Department for Children, Schools and Families, it really doesn't know how long teachers are retained and whether there are subject differences. There are suggestions, such as the one that Michael Gove has come up with, about paying off bursaries, and we would support that. We are less happy with his idea of the elite, because I don't think that there is necessarily a correlation between high-degree performance and quality of teaching. We certainly think that imaginative solutions like paying off the student loans for teachers who stay in the subject are a possible aid to retention. Finally, to reiterate something that was said earlier, it is important that the people in the profession get support and career progression. There are two things that I will mention on that. One is that, so often, a trainee teacher goes in and is expected to teach A-level from scratch, and they are the only physics teacher in the school. That is really unacceptable. Secondly, there needs to be some thought to career progression, perhaps in some sort of accredited form like you get in other professions, so that someone can go through the ranks from NQT—newly qualified teacher—then possibly through some intermediate stage to become an expert teacher and be recognised as such. Perhaps recognition should be given in the pay packet or something in that direction.

**Chairman:** I know that some people want to come in again, but I will have to hold you. We have six areas of questioning, and I am not going to get colleagues through them all.

**Q11 Mr Chaytor:** May I make one final quick point. Peter, we have mentioned the question of bursaries, and for teacher training we have particular incentives for shortage subjects. Coming back to the point that was made earlier about the pool of talent being reduced because only 22% of physics undergraduates are women, why don't we introduce cash incentives for women to study physics?

**Professor Main:** Would that be legal?

**Q12 Mr Chaytor:** Is that the only objection?

**Professor Main:** No. In fact, if you look at the people who are enrolling on teacher training, it is factually the case that more women proportionately do that. I think the proportion of teachers who are female is probably about 35%—I will check that figure<sup>2</sup>—so it is much higher.

**Mr Chaytor:** So, it is the converse of the problems of recruiting men into primary school teaching.

**Q13 Chairman:** Right. Just before we move on, Peter, you are strong on teacher training. Is there a guide, and does everyone know what are the best places to do teacher training for a scientist, for a physicist? Do we know that there are departments of excellence that are just damn good at it? John.

**Dr Oversby:** Two things about that. First, most of those people who go into science teacher training go to their local place. The value of league tables is, I think, largely questionable. The league tables that there are from Buckingham, and those from Ofsted, are largely dominated by the quality of the degree on entry.

**Q14 Chairman:** So there are no exemplar places where you can say that they really train science teachers well in that place. You are really telling me that there is no one specific site. We have just done an inquiry into the training of teachers, and of the 264 places where they train teachers, you're telling me that none of them stands out as good. Are they all the same?

**David Perks:** It is even worse than that. If you wanted to be trained in teaching physics in Birmingham, until the project with which I am involved—Physics Factory—got involved, you couldn't. It didn't exist. It is the other way round.

**Chairman:** That is probably a good thing if there are 264 other institutions offering it.

**David Perks:** Birmingham is a big place. It has two universities and no teacher training for physicists.

**Chairman:** John, you're shaking your head.

**Dr Oversby:** I am thinking of my colleagues in physics teacher training at Birmingham university. While the actual degree, the PGCE, might be described as "science with physics", as it is in the course that I used to be head of at Reading,

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<sup>2</sup> *Note by witness:* The actual figure is 28% so lower than I said but still substantially higher than the % graduating.

nevertheless, specialist physics is part of it. David's broad-brush approach actually hides a lot of really good specialist teaching for physics teachers in a wide number of areas. Ofsted produces grades for individual subjects, so if you want to use that as a criterion for where to study, you could do, but I have already made my point clear on the basis of what is best.

**Professor Holman:** To answer your question whether some places are better than others, of course they are. Some places are outstanding, and some places are not so good. Your question was also about whether there are ways in which undergraduates can find out about that, and as far as I know the answer is no. There are a number of indicators, but why would a young undergraduate in physics know which one to look for. Perhaps that is something we need to put right. I want to add one thing because it is important. The emphasis given to individual subjects in different teacher training institutions varies widely. Some universities might offer clear opportunities to train as a science teacher with a strong specialism in, say, chemistry or biology; others might not. That is linked partly to whether they offer an 11–16 PGCE or an 11–18 PGCE. If you can offer a PGCE for 11–18 teaching, you must offer experience of teaching in an 11–18 or a 16–18 institution, and that is more difficult to come across. A lot of teacher training focuses on 11–16 and tends usually—not exclusively if it is doing that—to be more generic across science, rather than focusing on a particular specialist subject. Everyone who trains for a PGCE should have an opportunity to train generically to teach science to 16, but also to specialise in a subject if they wish.

**Q15 Mr Timpson:** I was struck by something that David said earlier about subject knowledge and that, as far as he was concerned, it is still at the bottom of the agenda. Yet we know, because of the development through the TDA of the subject knowledge enhancement courses, that there is a real gap in subject knowledge. We heard again this morning that BTEC is now taking over from GCSE in many respects. John said that some universities are dropping their entry requirements for undergraduates, so there clearly is a demand for subject enhancement courses, but how are the students being identified? How do we know that they need them? How is it decided how they should be provided? Do we have enough courses to ensure that all those who require the gap in their subject knowledge to be filled are getting it?

**Dr Oversby:** I have experience of that. I was head of science teacher training at Reading. The people are identified in two ways. I am talking about the postgraduate course only. They apply for a traditional PGCE in one of the sciences and are identified as having inadequate subject knowledge. I certainly focused on subject knowledge first, so my experience is quite different from that of David. Those whose subject knowledge was not sufficient in our view after discussion, interview and looking at the qualifications were then recommended to go on

either a two-week booster course or a longer six-month course with bursary subject knowledge enhancement, which we still do at Reading. At Reading, we take students not only from the Reading course—those people who have been accepted to do the Reading PGCE or GTP—but those who are doing PGCEs or GTPs from the surrounding region. They know about us because they are part of the network. People are identified at the point of selection for teacher training, and the TDA itself has subject knowledge enhancement information prominently on its website. It is about recommendation, based on a whole range of information and subject knowledge from qualifications and subject knowledge through interview. It is important in my view and it is important in the view of my colleagues. The fact that subject knowledge enhancement courses exist shows that concern and willingness to do something about it is widespread. I hope that that reassures people.

**Professor Main:** Just a couple of points on that. We have been heavily involved in the physics enhancement project, offering mentoring support for the teachers. We have found that while what John has described as best practice—Reading has been very good—the marketing is very variable. You can go to the websites of many of the teacher training organisations and you will not even see reference to these enhancement courses. We feel that a lot more could be done on the marketing on that side. The other thing to mention is that we are working with a number of others, including the science learning centres, on mastery tests and measuring the knowledge base of people when they apply to do teacher training—also with the science addition specialism courses. We have been finding out and doing diagnostic tests to find the knowledge gaps in the people applying to do teacher training, so that that can be fixed.

**Professor Bell:** To follow that up, one of the issues always comes back to the length of time involved in people's training. If we take PGCE particularly, it is 36 weeks or thereabouts. As David pointed out, even if you say, "Let's keep it nice and narrow, teaching physics and nothing else", in your degree you are unlikely to cover the breadth of stuff that you would be expected to teach. That does not mean to say that you do not know it, but you need to rethink it for how you are going to teach it. The subject knowledge issue is twofold: making sure you yourself know some of the areas that you have perhaps got a bit rusty on, at best, or you never knew; and, at the other end, actually getting that breadth, and how you communicate that in an effective way within a programme. We just asked some people to do a bit of preliminary work on how subject knowledge is dealt with in PGCE courses as they stand, and on whether we can look beyond that to how we can recommend possible improvements—not always by adding bolt-ons but by incorporating it in the training that we provide for teachers. That brings me back to a point that Peter touched on: we have to stop thinking about teacher training being simply what you do pre-qualification, and getting qualified teacher

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status—it has to be a much longer process. You have to work out how you balance that, because your subject knowledge and your other stuff will be developing continuously. That is one of the things about science: knowledge does change. It is not the same as it was five years ago even, in some cases.

**Chairman:** I am going to bring Karen in.

**Q16 Ms Buck:** That leads into a question that is very much picking up on what David Perks was talking about, which is support in school and what happens after that initial teacher training in one school. That then leads to a question that, possibly, Peter referred to, implying that we could not quantify this. What about the tension? Do we know anything about physics teachers and chemistry teachers specifically, and their retention rates compared with others? We do not have any of that information. Is there anecdotal evidence? Is it harder to keep teachers who are specialised in science as opposed to other subjects?

**Professor Holman:** Anecdotally, I would say yes. They get promoted faster, because you are looking around for a head of physics because someone has just left, and you promote people faster. But I am not aware of any evidence. The overall number I do know—it goes back a bit—is that something like 40% leave the profession within the first five years. I think that that is the statistic for science teachers.

**Q17 Ms Buck:** How does that compare with general retention?

**Professor Holman:** I don't know.

**Q18 Ms Buck:** Is that something someone should do some work on?

**Professor Holman:** Yes, to get down into the detail and the granularity of the subject level.

**Q19 Ms Buck:** You have so many different angles: how do you get people into teacher training and into teaching, and how do you retain them in those subjects? Obviously, understanding whether different factors drive people in physics and chemistry—sciences—as opposed to more general teaching retention is worth knowing.

**Professor Holman:** I think there is something specific in science and particularly the physical sciences, physics and chemistry. People go into teaching from a combination of loving their subjects and wanting to work with children. What I am about to say is totally without evidence, but I am pretty sure it is true: people teaching physical science, on the spectrum between doing it because they love the subject and doing it because they love working with the children, tend to be more towards the love of the subject. I have no evidence at all, but I am pretty sure it is true. What that means—and this touches on something David said earlier—is that giving a physics teacher the opportunities to teach physics is very important. I used to be head teacher of a school where we taught a lot of separate-subject physics. When that awful moment came when a physics teacher retired—an awful thing to happen in the

school because you know you will have a nightmare replacing them—I knew that when I interviewed candidates, I could say, “Yup, you’ll be teaching a bit of A-level physics, some GCSE physics, because we offer separate triple-science GCSEs, and some combined science in year 7.” They would say, “Yes, that’s good. I quite like the idea of teaching some combined science, but I want to have a good dose of physics teaching.” Having that available to offer was an important part, I felt, of both attracting and retaining people. Clearly, in an 11–16 school, offering A-level isn’t an option, but I think it is important that such a school can offer physics teaching, so people could say, “I will be teaching my subject.” This is about the availability of triple science.

**Q20 Ms Buck:** I know David has something to contribute to this. Is it not possible for you to get your collective heads together and organise to commission some proper research into the tension and try to understand or quantify what you think anecdotally is right?

**Chairman:** We don’t want our special adviser, Professor Holman, to go into a decline, because he has done research on that.

**Professor Holman:** I think I was quoting that figure from—

**Chairman:** But you prefaced your remarks by saying that you don’t think any research has been done on this.

**Professor Holman:** No—I meant the comparison between the general picture for all teachers and the specific science teachers.

**Chairman:** He is open to commissions.

**Q21 Ms Buck:** May I ask about strategies for improving support for school teachers?

**David Perks:** There are some reasonably simple things that you could do. If you prioritise the sciences, you would want to prioritise mentoring schemes in schools and local authorities. I am working on a project to try to give physics teachers a voice together outside their schools. One of the things you feel, especially if you are a lone physicist, is the burden of the school weighing on you while you are there. But if you can get outside the school and meet other physics teachers, it is a different situation, and you can hopefully reinvigorate your enthusiasm for the core of what you are supposed to be doing and the subject you are supposed to be teaching. That is the basis of a model we can hopefully develop—“I know that I’m not the only one doing this.” On the other hand, there are contradictions in the way in which schools operate. We are supposed to have an entitlement so that if a youngster gets to level 6, whatever that means now—Key Stage 3—they should have the option to study separate sciences. In reality, that’s not really the way it works; it depends entirely on where you are and the pre-existing history of the school. But if that was given back an impetus, it would certainly have an effect on the ability to say that those teachers need some back up, and it is important in the system.

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**Q22 Ms Buck:** That sounds absolutely right, but what practical steps can be taken, given that you are in this difficult situation? If you don't have enough specialist staff to start with, how do you then create the mentoring opportunities and space for training and continuing professional development?

**David Perks:** In terms of working within schools, you have to bring together schools that are involved in developing their ability to deliver separate science teaching, or whatever it is, whether that is at GCSE or A-level. Again, that is the project that I am working on—a model to try to do that, work out what is possible and how it can work. I don't think that there is one answer; different circumstances demand different approaches. However, it needs back up, and the thing that we found is that people are very enthusiastic about the ideas, but it does not happen without some kind of resource backing, which is the more difficult part of it. There needs to be a priority that comes down from the top, and there must be funding to make that support of action happen.

**Dr Oversby:** What we heard from David is obviously a very good way forward, and working with mentors from other schools is absolutely a wonderful way to go. Through its network, the Institute of Physics does similar things. From my knowledge and experience, it is not quite so readily available in chemistry, and certainly I will be going back to the Royal Society of Chemistry and saying, "What a good idea. Let's help". It is not as good as having people on the ground—we would all acknowledge that—but we are in a real practical situation and these suggestions about having mentors elsewhere are good. I also want to say that, in teacher training, we do not really know a lot about the subject disciplines of mentors, but we do know that many of them are not in physics or in chemistry and that cannot be helpful. In Reading, we promoted the idea of what I called "associate mentors"—people who were specialised in physics or chemistry who worked with the students that we placed. We had a lot of chemistry and physics graduates, so I was doing well—I want to trumpet my success. What we did was to implement practical ways of dealing with the situation. If there are not physics teachers in schools—25% of comprehensive schools are without a physics teacher—in the short term we have to do something about it, and these proposals from colleagues on both sides of me are worth considering. Perhaps we should put more money into them.

**Q23 Ms Buck:** A last point from me. There is a fantastic phrase, which I think is yours: "Enculturation into teaching as a survival activity then takes over for too many."

**Dr Oversby:** Yes, I did say that. It starts often at interview. Many of my students came back from interview and said that they were asked to teach outside their subject discipline during the interview, as a way of seeing how they would cope. Too many of them are given classes that are difficult—large numbers of lower-school classes. John's example,

which is commendable, is not very common in my experience of dealing with hundreds of PGCE students going into their new career. Enculturation into the survival mode for the first few years is one reason why we have poor retention. Those who survive are then rewarded by being given A-level teaching and the rest of it. In one paper, I noticed that in some schools some of the leading teachers adjusted the teaching so that those people who were long term got the classes that involved teaching specialist sciences. That is unhelpful, and this notion that you have to get through large amounts of new teaching outside your subject confidence zone in the first few years is a major cause of people not carrying on. It is just as common that people who are trained in biology have to teach physics and chemistry topics. Imagine what that does to those children's confidence and their motivation for chemistry and physics. So it is bad news all round. Enculturation into survival mode is something that we have to tackle.

**Chairman:** Thank you, John. A quick point from you Peter, because Karen has to leave after this group of questions.

**Professor Main:** I just wanted to mention the Stimulating Physics Network, to which John was referring. I will not give details of it now, but if the Committee wants details, we can pass them on. It is a DCSF-funded partnership between us and the science learning centres. Clusters of schools are a good way of working, and the sort of project that David is working on is involved in that. The Ogden Trust is funding some of the physics factories with which David is involved. The specialist schools ought to be capable of being the centres of such clusters, but they are not at the moment because they are not what it says on the tin, so that is something you might want to look at. Finally, in terms of retention, there is the matter of looking at the professional career path from a subject point of view, as John Holman has said. Many STEM teachers see themselves as scientists as much as they see themselves as teachers, and getting a professional career path that is subject-based—CPD in schools is not—and perhaps linking to bodies such as the Institute of Physics, so that those teachers feel themselves to be physicists, would be a good way forward.

**Chairman:** Thank you. Karen, have you finished?

**Ms Buck:** Yes, thank you.

**Q24 Mr Timpson:** I am thinking about the image of science or the sciences. I have looked at the list we have been given of what action the Department and the TDA have taken to try to address many of the issues we have been discussing this morning, but none of them seems to tackle head on the image in the wider public domain of science or sciences. It made me start thinking about how it has been sold to children both in schools and elsewhere. For instance, until 2001, Michael Faraday was on the £20 note. We have now got Edward Elgar and Adam Smith—great people in their own areas, and I am sure the Bank of England is very happy about that. However,

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Michael Faraday no longer appears. What does that tell us about the image of science that we are selling to children? What should we be doing—over and above everything we discussed—in the classroom, in initial teacher training and in recruitment and retention, to try to improve the image of science?

**Professor Bell:** This is a very fundamental thing, and it is easy to say that we do not see science as part of our culture. A city in the north-west of England was the city of culture. Defining the word “science” in their promotion and publicity was not possible, because it was not there, and yet there were two major science conferences there during that year. What is now the British Science Association and the Association for Science Education both held their conferences up there specifically to promote and put science in that part of culture. A document I read recently that was all about culture defined it as art and humanities. It almost said, “Science might come in if it happens to be in the same museum.” So it is a deep-seated thing—this is easy to say and I know people say it—but it goes back to some of what David said at the beginning. It is about getting that enthusiasm for science and showing children, young people and adults what is fascinating there, regardless of everything else. It is that enthusiasm that gets it. The trouble is we are actually digging a hole for ourselves. How many times do you have to repeat, “Science is boring,” before someone starts to believe it? And sometimes we get ourselves into that negative spiral of saying, “It’s boring,” and forgetting it is really exciting. If we start saying, “It is exciting,” we start to think about it. So it is not necessarily just about the big publicity, which I think has been quite useful. Some of the TDA adverts for recruitment into teaching that focused on science really captured it. That has been absolutely tremendous, but if we say, “It’s boring,” that is what people hear, so it gets ingrained in a psychology that I do not fully understand.

**Chairman:** Everyone wants to have a go at this, so I would like you to be brief.

**David Perks:** In a way, I do not think it is a real problem. If you make the effort to get scientists to explain what they are up to, anyone will listen. I have been very lucky. I have had people like Brian Cox come to my school and explain CERN, before it broke—hopefully he will come back when it is fixed. That enraptured 300-plus kids, plus teachers, and really motivated the physics and science teachers who came along, so it sells itself. What we fail to see is that we are really good at it. Britain has on its soil somewhere as hot as the sun, if not hotter, that no one knows about. It still exists in the fusion lab in Didcot, Oxfordshire. We were at the forefront of developing that. We were at the forefront of developing all sorts of technology and science. We just have to have the confidence to say what we are doing. It is kind of a misnomer that there is nothing good to say—it is everywhere to be said. The mistake, if there is one, is to say that we should be targeting kids at a younger and younger age and developing enthusiasm in a kind of fake way with a sub-“Brainiac” approach to developing enthusiasm

for science. You do not need to do that. Tell people what it is that scientists actually do and they will work it out for themselves.

**Dr Oversby:** My history and philosophy of science project at Reading, funded by the European Commission, is primarily focused on the humanistic side, embedding a really serious subject knowledge within it. We are explaining why scientists measure, not in any abstract way but practical ways, by getting children to think about thermometry, temperature and how thermometers are constructed. We engage children in working in the classroom as scientists do, and in looking at some of the humanistic histories of the past about the people involved—that is another way. I am not saying that we should not have modern scientists, but we are not using the wonderful people from the past. It is mainly a heroes and villains approach. The children I have been working with on constructing play scripts and the like are really engaged with what is going on at a level the teachers say they could not imagine.

**Professor Main:** I agree with David. I don’t think the situation is as bad. There is so much science on TV and in the media at the moment. Brian Cox has been mentioned, and there is Jim Al-Khalili, so there is much more than in recent years. At the Institute we employed some marketing consultants—the people who sell toothpaste, so let’s sell physics like toothpaste—to go out and talk to kids in schools. They told us that physics in particular, and science in general, has a Rolls-Royce image—in other words everyone admires it. There are no bad feelings about science. Attitudes to science are incredibly positive across the whole country, including among school children. Like most people’s attitude to Rolls-Royces, however, they think that is wonderful but not for me, because I can’t do it or can’t afford it. The issue then becomes persuading people, making science more accessible, and getting them to have realistic career aspirations at the ages when they are making choices about subjects. My final point, which I made earlier, is about senior people. It is very important that senior people talk positively about science and that we move away from the culture that Derek alluded to of lots of people saying, “I was bad at science and mathematics when I was at school.” My goodness, there are a lot of people who say that.

**Q25 Chairman:** You are all scientists, but can I throw the ball back in your court? When I first became Chair of what was then the Education Subcommittee of the Education and Employment Committee, we took with us to look at early years a psychologist who was an expert in the development of the human brain. John, you did the amusing thing about the relationship between the ambient temperature and the possibility of studying science. Yet, are we not looking at the science that understands the development of the human brain and how best to stimulate that brain to be engaged in scientific inquiry? For instance, are certain kinds of human brain more prone to science than other

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subjects? Should you go back to the core science of how the human brain develops and can be engaged in science?

**Professor Holman:** Do you mean for the teachers or the pupils?

**Chairman:** For the pupils.

**Professor Holman:** It is fascinating but a very incomplete science. It is developing science—one of the fastest growing fields is neuroscience. To agree a settled curriculum around neuroscience would be challenging.

**Q26 Chairman:** But, John, we now know. Ten years ago we did not know as much about the importance of early-years stimulation of a child's brain. A lot of research is coming out that a lack of stimulation up to 22 months can change the pattern of life after 22 months. That is frightening. Are there things that we can do with children's stimulation to make them more prone to a scientific attitude to life?

**Professor Holman:** I am sure that there are.

**Q27 Chairman:** Why aren't you doing it? You're scientists. You do not seem to be using science to understand what motivates a human being.

**Professor Holman:** There is a lot of babble that goes on around this among teachers, I'm afraid. Because it is a developing field and the knowledge is incomplete, there is a tendency for teachers to pick up incomplete knowledge about left brain and right brain, and the beginnings of a bit of neuroscience, which in some cases you are better off not having at all. It is something that you either have to study and understand in some depth, or not use at all.

**Q28 Chairman:** But there is total information, isn't there? There is no dispute about the importance of stimulating a child in its early years.

**Professor Holman:** You do not need to know neuroscience to know that.

**Chairman:** A lot of science has added to our understanding.

**Professor Holman:** It has. It has brought precision to it, but you would have to go into that science an awful lot before a teacher's instinctive learned behaviours would be improved by an understanding of neuroscience.

**Q29 Chairman:** Neuroscience takes us away from this, but is there no scientific application of science in terms of understanding how children respond to certain teaching and learning environments? Surely that is rather important. When I go to a school, I know when science is well taught and when it is awfully taught. You seem to be floundering around and saying, "Well, we don't quite know."

**Professor Main:** You seem to be mixing two things. You seem to be mixing what might be called educational research into whether certain sorts of science teaching might be effective, and neuroscience. I guess you are referring to studies of functional MRI and so on, where you are seeing how the brain responds to certain stimuli. The latter is interesting; it is rapidly growing, but it is a long way

from telling us the best way to stimulate people to make them scientists in the future. At the moment, that is science fiction. You are absolutely right that one can go into schools—I am sure Ofsted does it all the time—and see what sorts of lessons stimulate the kids. Our view at the Institute is that science education at primary level should all be about "gee whiz" and stimulation, and the idea of teaching science formally at that level is probably a mistake. But that is certainly not on a neuroscientific basis; it is based on experience of seeing what motivates children in an educational environment.

**Q30 Chairman:** But David alluded to the fact that understanding science in the very early years can be done in an exciting and challenging way, but it seems that we are not doing it in a systematic way in our schools.

**David Perks:** You have thrown a few red herrings into this.

**Chairman:** That is my job.

**David Perks:** Fair enough. I am suspicious when anyone says that we are teaching brains, not children. We might as well then say that we are teaching genes, not children—where do you stop? We are not machines, biochemical or otherwise; we are human beings, and that is my starting point. Obviously, neuroscience has something to add to that, but to extrapolate from that we should learn from neuroscience and not the other way round is a bit of a mistake. It is trying to find the fish oil that will suddenly be put in the diet to solve all our problems—there is not any. The problem is that we are trying to teach young people our collective knowledge, which we have developed over centuries, about science in the natural world. That is hard work. We cannot get away from it, and to find a trick or the quick way of doing it is wrong. We have to believe that it is worth doing. If we do, we will value the people who put themselves up to do it. We can then start really finding out how it works, and the best way to do it. At the moment, we are not at that stage.

**Q31 Chairman:** Why do the independent schools seem to be so much better at it than state schools?

**David Perks:** I do not think that they are.

**Chairman:** They certainly turn out more scientists pro rata.

**David Perks:** Some do.

**Chairman:** They do.

**David Perks:** Some do not.

**Professor Holman:** If you measure it by A-level physics and all the A-level sciences, yes. You are touching on an important point, which is around the ethos of the school. We heard Edward's point about the image of science. Well, science has an image in society as a whole, coloured by things like Faraday on £20 notes. It also has an image within an individual school, and young people go around a school thinking about science and their future studies of science that will be coloured by their experiences in that school. We really need to be concentrating on that. What can we do about the

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ethos of a school that makes the image of science and mathematics within that school positive? Above all, it is great teachers; well-trained, subject specialist teachers. It's about bringing good role models of scientists into the classroom. Not everyone can get Brian Cox into their classrooms, but there are plenty of good, positive role models of scientists. It is about doing that and celebrating science and saying, "If you want to, you can study three separate sciences". Every school should have triple science available as a study option. That says something about the importance of science within that school. It is also something to do with the fact that science and mathematics are perceived to be hard subjects. In most schools you would find people who say, "Which are the hardest subjects and which are the easy ones?" People will say, "Science is among the harder ones." You decide whether there is evidence for that or not. Schools that are successful in science and mathematics manage to create an atmosphere that actually celebrates the fact that these are challenging subjects; that they are provoking and in the best sense challenging and difficult subjects. They celebrate the fact that they are difficult, and highlight the rewards that come from sticking with these subjects. The rewards are very clear in terms of the employment prospects and life chances that open up. Going back to your point about independent schools, it's about a combination of things, one of which is that they often pick the brightest kids anyway, so that is obviously going to make a difference. Another is that they tend to get very well qualified teachers, and that makes a big difference, often because they pay them more. The third point is that the most successful schools create a kind of can-do atmosphere: all right, science and mathematics may be challenging, but you can do them, you can succeed, and if you stick with them, you will go to great places.

**David Perks:** And that is the same in the state sector as well. It is not different. Good state schools do the same thing—they may have a bit more baggage to carry around with them, but it happens.

**Q32 Chairman:** David, I am trying to get you slightly out of your comfort zone and bang some ideas at you. When I look at Derek, I see the wonderful thing that the Wellcome Trust did in Darwin's year, last year, in terms of the kits that were sent in—I saw children using them in classrooms, and suddenly coming alive to science in a way that I hadn't seen before. What I am trying to push is, aren't there ways—I will stop my question because Derek wants to come in.

**Professor Bell:** Following up on that question, thank you for mentioning the kit. For those who don't know, we sent a kit of things for studying plants to every primary school and we know that at least 14,000 of the 25,000 involved are using them. We did similar kits for secondary schools. They had to ask for them because there was some living material in one of the kits, but it got to 70%. If I was a marketing man, to get penetration of 70% into a market, that is brilliant. However, the point about those was not

that there was a recipe of how to do it but that it provided a framework that teachers could pick up and use. They were given the resources, the back-up and the instructions on how to use it. At the end of the day, it was down to them and to how they used it with their children. It was flexible. That goes back to what David said. David and I have disagreements about certain things, but we are both absolutely spot on about this. It's about how you work with those children. There is no recipe that does it. I was at a Cambridge Primary Review session last week, and one of the things that they talked about was moving from a recipe for teaching to a repertoire for teaching. If there is one thing that has happened that I would say we got completely wrong when we started to revise teacher training over the last few years, it is that as we started to get the standards in place, which became very tick-boxy as to how you do it, that actually reduced the opportunity for young teachers—and older teachers, for that matter—to develop a real repertoire of how to deal with particular situations. In one situation, you might be teaching the same subject to a group of students and they will react in a particular way. You need to react to that in order to take them forward. In another circumstance, you will get a different reaction. You need to be able to adapt and react to students to get them enthused. It is about that repertoire and that relationship between the pupils and the teachers, built within an ethos of genuine learning in schools, as John says. That could be taken even bigger in the country.

**Q33 Paul Holmes:** The Committee has just finished a report on teacher training, which is due to be published shortly. One big part of the issue before us is initial teacher training, and the other is what happens in the first and second years of teaching and during ongoing professional development. The Association for Science Education has commented that it can be quite difficult for teachers to get subject-specific training once they are in school, because schools tend to focus on whole-school issues. When I was a history teacher with a sixth form in the 1990s, the school very much emphasised whatever Ofsted had criticised in its last report or what it was likely to look at on its next visit because of a new Government directive. What do we do about that?

**Professor Main:** I come back to what I said earlier. You're absolutely right about CPD in schools not being subject-specific. We can offer subject-specific CPD to them, and the science learning centres were, of course, set up to offer excellent support. But what it really comes down to is that if you want to be serious about this, there has to be a carrot or a stick. In other words, there has to be some sort of requirement for teachers to maintain subject-specific knowledge. That is very common in other professions, and I see no reason at all why it should not be common in schools. But linked to that—you can call it the stick side if you like, and it would involve some sort of licensing or accreditation process—could be the carrot side, so that if you

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attain accreditation and are deemed to be, say, an expert physics teacher, you might expect some sort of career progression or financial reward in the school. But unless you link the career progression or some sort of career requirement to subject-specific knowledge, with the best will in the world, and however good the provision is, teachers will not take too much notice.

**Q34 Paul Holmes:** The Government's proposed licence to teach would seem to fit what you've just said.

**Professor Main:** Provided it has a subject-specific basis—that's the key point. All too often, things such as the Masters in Teaching and Learning are fine, but there is very little subject-specific material in there. It comes back to what John was saying earlier. Many STEM teachers see themselves as scientists as much as teachers, and the subject-specific side—the subject is changing as well—is very important.

**Dr Oversby:** I am going to disagree with that view; it is predicated on information and thinking mainly about sixth forms, where it might be more relevant. For me, the more significant issues are to do with pedagogy, not subject knowledge in teaching, and it's a big challenge particularly for physical science teachers—physics and chemistry teachers—who come from university with a secure and robust idea of what their subject knowledge is. Despite what we've said about everything changing, a lot of it is not, and school science is not changing as much, perhaps, as the stuff outside. We might say that's a good thing, or we might not, but that's what it is. What is changing is our method of engaging children and involving them in argumentation and discussions. I've been doing work on getting children to create their own play scripts about scientists at work and to embody some of their subject knowledge in those scripts. That is a major need, because I've discovered that many physics and chemistry teachers—this is not true of all of them, because we have taken in a lot of physics and chemistry graduate teachers—lack skills in engaging with the children. Teaching those teachers the pedagogy of engaging with the children comes first and foremost. When we've done that and given teachers the skills they need to relate to children in more open-ended and interactive ways, subject knowledge might come next, but I am not of the view that developing subject knowledge is the most important thing. I have been involved in physics and chemistry teaching for the last 40 years, and I've done very little to improve my chemistry and physics knowledge since I stopped my studies, and I don't think that that's been a big disadvantage. I have improved my pedagogical knowledge, and that is what has made me a successful teacher.

**Q35 Paul Holmes:** When we were in Canada as part of our inquiry into teacher training, we talked to people at universities, and they said, "It's not our job to teach the tricks of the trade. They'll do that when

they get to school. We are here to teach about the subject and about the psychology of education and so forth."

**Professor Main:** Could I—

**Chairman:** Hang on—no, John then Peter.

**Professor Holman:** I hope that John and Peter are not saying different things. John is talking about pedagogy—that is, teaching skills and ways to teach effectively. The best way to do that, if you are a physics teacher, is to learn it within the context of a piece of physics, not to learn it as an isolated "This is how you carry out a group activity" or "This is how you carry out coaching." Do it within the context of that piece of subject knowledge. This is what we do at the science learning centres. We are mostly about pedagogy—better use of ICT and teaching, for example—but it is always within the context of a subject. That is the right way to do it, because secondary teachers, at least, see themselves generally as subject specialists. They like to carry out their professional development within the context of their subjects. I was not detecting anything substantially different between what Peter and John said.

**Professor Main:** I was going to say almost exactly that. Of course pedagogy is the important thing, but you need to have the subject knowledge. I want to add one more thing. There is a particular problem in physics: a lot of physics pre-GCSE is taught by non-specialists—people who do not have physics beyond A-level. We have done a lot of work with them in the pilot work for the Stimulating Physics Network and in the network itself. I can assure you, subject knowledge is a major problem there. We know, for example, that the majority of the non-specialist teachers we were working with did not understand Newton's laws of motion.

**David Perks:** I completely disagree with John, I am afraid. I think that what you are alluding to is some of the new pedagogy, which is being imposed on science through changes in the curriculum over the past five to 10 years. That is next on the list, I think. The "how science works" approach is one way of categorising it. I shall give you an example. The core activity of a science lesson is—or should be—learning the experimental method. What has that got to do with argumentation? Not a lot as far as I am concerned. What has happened is that there has been a shift away from looking at science as a lab-based activity to looking at science as having some kind of citizenship focus—"science for the citizen"—in which you argue the case for whether or not evidence backs up particular points of view, so that you can make an informed choice as a user of science, rather than as a scientist. This is a massive shift that has occurred, basically since the last GCSE reforms, in how science education is perceived. That is why pedagogy is so important, because what you are trying to say to teachers as they come in is, "You are not a teacher any more", because it is not the subject that is important, but the discursive approach to science as a social set of skills in preference to the lab-based, experimental set of skills. This is a core problem in terms of how new

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teachers understand science education and how we develop the curriculum in the future. It is no surprise that John is very keen on pedagogy and not on science as the core of teacher training or CPD. I say that it should be completely the other way around. Reinvigorating experimental science in schools is a massive problem that we have to deal with. It suffered badly under the previous GCSE system—the so-called double science system—and it is now getting even worse. I think that is where you need to understand this, by looking at that problem.

**Professor Bell:** This is where David and I diverge slightly—it is partly nuanced. What he has described is correct to the extent that that is how “how science works” has been interpreted and presented in the media. Actually, if you go back to the original programmes of study, which are the statutory requirements for Key Stage 4, which is where it all started, they talk about four categories. First is the use of data evidence, theories and explanations—that is, the critical and analytical thinking based on evidence. The practical and inquiry skills are about developing how you actually use a thermometer, plan experiments, carry them out accurately, do your readings and all that side of it. There are communication skills—there is no point having found this out without being able to explain it and argue your solution and hypothesis to test it to ensure that it’s rigid and whether you need more evidence. Then there are the application implications of science: “Okay, we know this; what are we able to do with it? What has happened as a result? Are there any implications? Just because we can do certain things, particularly in the biological world around stem cells, does that mean it’s appropriate?” You can argue and dispute when you should have those levels of discussion and what form they should take, but “how science works” when it was originally conceived was about strengthening the rigour of the science and putting it into a slightly wider context, as opposed to it being isolated and have nothing to do with real life.

**Q36 Paul Holmes:** Leaving aside for the moment the arguments about what is the professional development that is needed, whether it is subject content or pedagogy, can science teachers access what they need? Professor Holman is director of the National Science Learning Centre, which leads on to regional centres. David is at the sharp end—actually in a school. From the two different perspectives, do we have a structure that allows science teachers to access the ongoing training that they need?

**Chairman:** Let’s start with Derek again, only because I think that that wing has been slightly quiet.

**Professor Bell:** It’s unusual for me to be quiet. I think the question goes back to what I said: it is not black and white—we all agree that you need both. The provision is out there, certainly, through the network of science learning centres and other providers in local authorities. There is potential, but probably not the sufficient specific subject knowledge that we would like. That is partly because of the response—teachers don’t tend to look for those courses, despite

what they said in the survey that Wellcome commissioned about five years ago. They said they wanted subject-based and subject knowledge courses, but they didn’t attend them because they attend exam provision and those sorts of things. Coming back to your point about Canada, if I understood you right, it was a case of, “We do this in the university, and that happens in schools.” I think, in a sense, that that is something that happens here in terms of training teachers, whether it is initial training or professional development. We don’t actually know who does what. You can actually characterise it and say, “We think they are doing this subject stuff in schools, but they may not be. We think they are doing it in universities, but they may not be.” We don’t actually know where an individual teacher gets that combination of knowledge and skills that they need to be a teacher. That is one of the things that we have to look at carefully.

**David Perks:** I agree with the way that you’ve described it. Teachers will say that they want it, but they end up going on the Ofsted prep or whatever. That is because it isn’t their choice—it’s quite straightforward: it is the school’s choice. If it doesn’t fit the priorities of the school, what’s the point of it. Unless you prioritise subject specialism and knowledge in a way that schools understand, which means that it has to be very plain, it’s not going to happen.

**Q37 Chairman:** But surely, specialist science schools—we were going to crack that—were going to be the places. Was it you who said that they don’t do what it says on the tin?

**Professor Main:** That was me.

**Chairman:** Why don’t they?

**Professor Main:** The word “specialist” is a rather delicate one. It doesn’t really mean anything when you analyse it and when people talk about specialist teachers. We have a seminar in the Institute on Friday looking at this very issue. The specialist schools can be specialist because they are excellent, but they can also be specialist because they aspire to be excellent. We know that many specialist schools and colleges, for example, do not have a teacher with physics beyond A-level as part of their staff. If you really want to make use of the specialist schools and colleges in a way that can drive all sorts of things, such as subject development and placements for PGCE students, what you really need to do is convert them from being what they are at the moment into centres of excellence. Frankly, what happens with specialist schools is that you get extra money for being a specialist school, so you look down the list to see which ones are left for us to choose, in some cases. That’s not true for all of them, but it can be true for some of them. Smithers and Robinson have done work, for example, to show that music specialist schools get better science results than science specialist schools.

**Chairman:** Let’s move on. That takes us nicely into the curriculum.

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**Q38 Helen Southworth:** I don't want to start with the curriculum, actually; I want to come at it obliquely and ask about the challenge of real life in science in schools. People tell me that part of the reason why young people don't engage in science isn't so much that they don't find it exciting as that they don't think it will give them a job at the end. I find that an interesting theory, because I happen to be the Member of Parliament for Warrington. For the past 250 years, science has created all the employment in the area, and it continues to be a major provider of employment. The reason why I was drawn to this is that somebody—I think it might have been you, John—said that you had engaged the people who sell toothpaste.

**Professor Main:** That was me.

**Helen Southworth:** You engaged the people who sell toothpaste, and it came into my head, "I wonder how we engage the people who make toothpaste?" Unilever are hugely important in my constituency and have been for a long, long time. They tell me in exciting detail about the content of the things that you find on your shelf in the morning when you get up. How important is industry and pure research in the process of engaging young people in schools and giving teachers a buzz as well?

**Dr Oversby:** Our "how science works" focuses on research and not on the vast majority of what is carried out in science, which one of my applicants described to me recently as largely being a lab rat. There is a lot of good science out there, which is not doing research, which can be interesting and valuable and all the rest of it. I think if we want people to know about the sorts of things that scientists do, we have to give the research bit and all the other bits. In my section in Thames Valley, we are in trouble with the Royal Society of Chemistry for spending too much money engaging industrialists to come speak in schools.

**Chairman:** Peter. You mustn't mention Reading in your answer.

**Professor Main:** I can mention Reading in a different context. I think there is a real issue here about what we know about how students make choices about careers. I have a slogan, which was actually picked up by the Minister, that you can do almost anything you can do with an English degree with a physics degree, but there are plenty of things you can do with a physics degree that you can't do with an English degree. Yet most pupils in schools think precisely the opposite, if you speak to them. They see English as a very flexible discipline and physics as a very narrow one. What we need to do is to look at the way that people make choices and what drives them to make these choices. I would offer one word of caution about getting too many industrialists and selling STEM. When we are young, we are very idealistic, and we see ourselves in ways that perhaps we won't see ourselves when we're older. If, when we bring people in, we are talking about very concrete jobs like widget manufacturing and goodness knows what else, there is a real danger that we will show STEM to be a little bit boring in a way that we are not showing other subjects, because we are not

making the effort in other subjects. What I suggest is that we need to do a lot of work in careers advice, but not just in STEM. Let's talk about careers across the whole spectrum, and let's try to engage young children with what is possible from certain career directions. Rather than just saying, "This is what you can do with STEM," let's talk about all the subjects.

**David Perks:** A couple of things: one is that the reason why it would be really good to encourage a more open relationship between industry and schools is to say what's important to industry from schools and to clarify the common mistakes that young people make, say, at A-level, where they don't do maths when they do science, or whatever. That is just horrendous. When the AS-level came in, that was one of the big problems that sat on top of the other problems we have in terms of where young people go after they've done their A-levels. They can opt out far too easily. Because there's a bit more choice, they say, "I'm going to keep it broad. Maths is too hard" etc. If someone comes in and says, "No, you can't go anywhere without maths," that at least makes them do a double take. That's really important because it's not in the interests of schools to push that.

**Q39 Chairman:** But, David, that comes back to the question that annoyed you all: we got into neuroscience and so on. It seems to me that scientists have not really studied why so many children early on seem not to respond to learning through mathematics.

**David Perks:** I am talking about a slightly different issue. In the past, it was an assumption that you did maths with science. It was built into the way education was delivered, at A-level at least. Something we need to build back is the not compulsory, maybe, but near enough compulsory idea that science is useless without mathematics—its language. That's different. It's a social thing. It's not—

**Q40 Chairman:** But, David, we've agreed. This Committee knows very well, from when we looked into how children learn to read, that there's an enormous amount of research on how you get children into reading. We know that you can use a variety of methods, including phonics, synthetic phonics and all that. We know about that and we know the importance of it, but I haven't seen the parallel in terms of getting children into science and maths—the same quality of study on just how you do it. It's kind of literacy in another world, isn't it? People are good at getting kids into understanding the English language, but you don't seem to be very good at getting little kids into the language of science or mathematics.

**David Perks:** Personally, I think I am—but let's leave that there. The essence of the literacy problem is important because the way literacy is understood in terms of science is literacy in the sense of what a non-scientist would need from science. The mistake is that we could then say, as you put it yourself, "No,

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don't do that." What is the literacy we need to base scientific education on that would then encourage more scientific education, not push it to one side. I would be very interested to know how we could develop some kind of project like that, because the opposite is happening.

**Q41 Helen Southworth:** Perhaps I can help you, Chairman, because the next question that I was going to ask was about engaging young people in practical aspects of science within the curriculum. I was going to say that, as a constituency MP, I had found few things more interesting than going to United Utilities laboratories and finding out what lives in water and how they deal with it, although the people there did a pretty good job of interesting me in their sewage works as well. That was also fascinating. The reason it was fascinating was that it took me back many decades to stuff I had done at school in the biology labs and going out collecting stuff from ditches. It reminded me of how interesting it is watching those little bugs—little rotifers. They were always my favourites. I can remember from decades ago the classroom work that was related to reality, but there is something that's more exciting than that, and it's going to Daresbury laboratory and finding out how pure physics makes better chocolate and identifies cancer cells that are the size of a full stop. So in terms of the curriculum, is it working?

**David Perks:** The one selling point that science has over other subjects at the beginning of secondary school is the science lab. It's our huge asset. Young people come to school and they want to get in the science lab. They want to do experiments. That should be our unique selling point. It should be the thing that we stress and make much of. Then even if the experiments you are doing are pretty basic, the idea that you're getting across to young people is that they can do experiments themselves. Once that idea is in their heads, then they're off; they've got the bug, which they then may be able to use later on as part of their career. But it is drifting a little bit too much away from that. So by stressing "how science works" in the way that it's understood now—although I do recognise what Derek was saying—it does key in far too much to things other than the experimental work in labs: the lab work. There is a big move to try and devalue lab work as one approach within science and therefore stress other approaches, which might be argumentation, media, analysis of statistics, etc. Now, however valid you think that is, it's not the core activity of science. The core activity of science is experimental work in labs, and that's what it should be.

**Professor Holman:** Practical work is really important for science, for all those reasons and those that David said, but the reality is that this country, when you compare it with other countries, actually does a lot of practical work. Our schools are very well equipped for practical work; we've got excellent technician support. People from the US come to look at our schools, and they've never even heard of a school laboratory technician; so we're well set up

to do it, and we do a lot of it, when you make international comparisons. However, there are pressures on practical work, and David's mentioned one of them. Another is, in some schools, health and safety, and an over-reaction to health and safety concerns. Another one is about assessment of practical work, because assessment drives everything that happens in schools. Getting your GCSE grades is very important; and part of GCSE science is an assessment of practical work. What has tended to happen is that schools have produced formulaic ways of doing experiments, which basically repeat the same experiment over and again, to yield the best possible grade towards GCSE. That has tended to depress the tendency to do interesting practical work, where you make some discoveries for yourself and have got some control over it, into something much more formulaic. So the summary is that you are right: practical work is very important; we are well set up to do it, but it's under some pressures, and we need to push back on them.

**Professor Main:** I strongly agree with John on that last point. I just wanted to add one point about your visit, going to Daresbury and places like that. We did a project with the Industrial Trust, where we set up visits of that type, and it was properly evaluated; we evaluated with the teachers and pupils. We found that one has to be extremely careful with such visits. They often put students off as much as they encourage them, particularly girls. We found that girls were very likely to be put off by a visit to a technically complicated facility, such as certain parts of Daresbury can be. Even if you put that to one side, with all the students what you really had to do was adequate preparation and adequate post-visit discussion in order to make the visit valuable. Just doing the visit itself could be counter-productive.

**Q42 Chairman:** David, you seemed unhappy about that. When I have visited science centres—and I have visited two regions, and one at the York centre—what was absolutely fascinating was seeing teachers being taught better how to use the external environment to teach science. Do you want to stay in the laboratory all the time?

**David Perks:** No, absolutely not. What I don't understand is this idea that girls can't get it, unless you do something nice, or whatever—I'm being facetious—unless you modify it so that it somehow feminises what you're doing. I just absolutely do not see that, from 22 years' experience. It doesn't work that way. The problem of why girls do or do not do a subject like physics—and it is the last bastion of gender biasing in education, as far as I can see, in schools—is a different question. It's about expectations. But when girls do do physics they do it really well. They come out really well, and I've sent them off to Oxford and Cambridge and all the rest of it. No problem.

**Chairman:** And Reading.

**David Perks:** I'm not sure.

**Q43 Helen Southworth:** Over the past 13 years, we have seen some wonderful and significant advances at Daresbury laboratory, and I have to throw in one

of them—the changing nature of the scientists. There are far more smart women in senior positions in Daresbury than there were when I was first elected. That in itself is significant because if girls hear the message that “they don’t get it”, they won’t and they will look for something else. They will not waste time or do something that will waste their resources. They should see role models who show what their good teachers are saying, which is that they can do what they want, or who defy what their inadequate teachers are saying, which is that girls do not do that sort of thing.

**Chairman:** We are running out of time, so let us have some quick answers on that one.

**Professor Main:** It is difficult to have a quick answer on girls and physics. David has caricatured the work that goes ahead. In physics, the drop-off is at one place, and one place only. You are absolutely right about more women at senior levels. The percentage of women lecturers in physics and physics departments is now the same as the number of physics graduates; it is carrying through. The big drop-off is between GCSE and A-level. It is wholly there. Once we pass that point, women do not drop out of physics at a great rate—any more than they do out of any other subject.

**Q44 Helen Southworth:** Is that a significant point where we need intervention?

**Professor Main:** Yes, that is the point. It is not a question of feminising in the way that David said. Although the Institute has done an enormous amount of work in this area—I can send reports to you if you wish—there is a lot of practice in schools that does put girls off the subject. There are issues about whether brains are different and all that sort of thing, but there are many things that can be done to help the matter.

**Dr Oversby:** If you have good science education pedagogy, you can do practical work that is absolutely vital, and have all the other things, too.

**Chairman:** It is very healthy having these different opinions.

**Q45 Helen Southworth:** Can I ask a final question about the international GCSE. Do you think that it enhances specialisms and stretches people? If so, should we be doing more about it?

**Dr Oversby:** It is a very traditional and limiting route in my view. Good science teaching can be done through our GCSEs. I see the IGCSE as something that we give to other people or something that is done abroad. If they want to take it, fine, but I do not think that it is for us.

**David Perks:** I do not see anything wrong with it, but it is not that demanding, bizarrely. It is linear, and we operate modular systems at GCSE, which I have a real problem with in the sense that they break the continuity of the subject into chunks. Anything that does that undermines your ability to connect your subject together. Kids will shut off because they have done that bit, so you cannot make those bridges very easily. That is a real problem at A-level as well. The other problem is that people can re-sit the modules,

so we get this culture of sitting modules again and again and again. That happens en masse to boost the statistics, so we are not really sure what is going on. The advantage of a linear course is that the child can start at one level and develop over two years. We judge them when they have developed, and not at bits on the way. There is something very strong to say about that for difficult subjects such as physics and other subjects. You give the child a chance to develop over two years, rather than trying to judge them constantly.

**Professor Holman:** IGCSE will be for only 10% or so of the population. We should not sweat too much about IGCSE, but concentrate on doing two things. First, we must ensure that every school in the country offers the option of triple science—separate physics, chemistry and biology. At the moment, only about 60% of maintained schools offer it; it must be 100%. Secondly, we should make the English GCSEs in physics, chemistry and biology more rigorous, challenging and more mathematical than they are at the moment.

**Professor Bell:** It is almost horses for courses. In the end, it is just a way of measuring. You will get one set of results with one thing and whatever. More fundamentally, it is how you conceptualise the whole process. I am not a scientist. I do not think of myself as a scientist anyway. I am basically a teacher. It is about getting kids interested in things, helping them to see the big picture rather than atomising a curriculum, which is what we have tended to do. That is what David is describing. The modular stuff has some advantages but, because it stops kids thinking, how does that one link with the next one? It actually creates problems, and we must work through that. It is about how we work with the children. As for the exams, you can put almost anything there. The trouble is that the schools are judged by how they perform in those things and that goes right back to David’s point: switching to BTEC is appropriate for some students, but—I am slightly cynical—a lot of the reasons for doing it is that it will help schools go up the league tables.

**Professor Main:** The IGCSE is in some senses a red herring. What happened was that a number of independent schools decided that they did not want to do the new GCSEs and took the nearest refuge. I do not think that they did it for positive reasons, but for slightly negative reasons and that is not somewhere we should go. However, there is an issue around GCSEs. I agree with what John said, but a tension has not been resolved, which is to do with whether the purpose of GCSEs is for scientific literacy or to inspire and prepare the next generation of scientists. The “one size fits all” that we have at the moment may not be quite the right answer, but I do not think that GCSEs are either.

**Q46 Paul Holmes:** Given all the angst that we have heard several times this morning about whether all schools should be offering three separate sciences, if we could get enough science teachers to offer three separate sciences in every school, would there be the take-up? It is 30% of a pupil’s curriculum, even

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before we get on to maths, English, history, geography, sport, music and ICT. Is there the demand for three separate sciences in every school in the country?

**Professor Holman:** There are a number of models for three separate sciences, one of which allocates 30% of the curriculum time. Another starts doing them in year 9 so that they get the extra time then rather than in year 10. It does not inevitably use up option time. I was head of a school that offered triple science, and about half the pupils in the school opted for it. Yesterday, I went to Leytonstone school in east London. It is a full-range comprehensive school, with 30% free school meals. It offers triple science, and about half its pupils choose that option. It is popular—there is a demand for it. Parents very much appreciate having it put on the menu, and it should be there in every school so that people have a choice.

**David Perks:** Three years ago, my school instituted a policy whereby every child did it. That is pretty unique in the state system. We did it pretty well; there was an 80% A\*–C take-up across the three sciences. In other words, it can be done. We did it to prove that it was possible. I am not saying that our school is in a deprived area, but it has a broad spectrum of intake. But it is a misnomer to say that that is too hard. If we look at what the GCSEs contain, we would be quite shocked at the low demand of some questioning, especially as each paper has a foundation paper. There is nothing to stop any child doing it at all. I am particularly of the opinion, why not just do separate sciences full stop, and just cut the rest of it out? That way, we give every child a sense of where they are in their understanding of those sciences. They know what they are doing, and the parents know what they are doing—rather than qualifications that they cannot make head nor tail of—and employers can value it. There is a really strong case for doing that, up to 16. Once they get beyond that, it is their choice.

**Professor Main:** Just two slightly oblique statements. First, I would not want people to think that if they want to do science, they have to do triple science. That is a real danger, as it would cut off a large number of people who currently do A-level. We must avoid that. Secondly, not only are all the people on the panel men, but they are all of a certain age. Most of us came through a system where science was not compulsory up to the age of 16. I, for one, did not choose all the sciences. I did not choose biology. There is a school of thought that, if you make it a choice, you can sell the subject rather better at an earlier stage and get more people to come through, certainly more enthusiastically.

**Q47 Paul Holmes:** Can I just start on what you said a minute ago, Peter? If children do combined dual-award science, which all three of my kids have done, is that not a serious disadvantage to them if they want to go on and do A-level science and university science? Are you saying that it is not?

**Professor Main:** It shouldn't be. That is a rather complicated question because we are getting messages now from the teachers who engage with the Institute that the new GCSEs are leaving a few holes in the preparation for A-level physics. I keep an open mind on the new GCSEs. I am certainly not opposed to them, but there are issues associated with them, one of which is the degree to which they prepare people. But that might be true of the triple sciences as well as the double sciences. In principle, the answer to your question is that I don't think there should be a problem, but there is a tension. If one really tries to push triple science more and more so that, for example, half of people are doing triple science, there really will be a question mark over whether the double science people are sufficiently well prepared, if the majority of those carrying on to A-level are from triple science.

**Q48 Chairman:** David, you're more of a young Turk, aren't you?

**David Perks:** In terms of what you just said, there is no doubt that the new equivalent to double science, the core additional route, covers less than the previous double science route. You also have to understand that a significant change is that a lot of youngsters are now doing only one science, when previously they had to do two, and so the number doing only one—the core—is increasing. When you understand it like that, the only result of this pressure must be to devalue A-levels, in the sense that you have to lower their content to match the GCSEs. That is exactly what has happened in the recent review of A-levels. No doubt that process is going to knock on again. So, what are we doing this for? Are we doing it to match things up, or do we not say, "Stop. Hold on. Teach the content and then see how far the kids get when they sit their exams"? Then they can judge whether they can make the jump to A-level, rather than everything having to be shoved down.

**Q49 Paul Holmes:** But on the other hand, we have always specialised far more at 13, 16 and A-level than most other competitor western European countries, which have longer degrees because in the first year of a degree they do the stuff that we would normally do at A-level. Should the university tail wag the dog of the entire school population by saying, "Specialise, specialise, specialise, from an early age"?

**David Perks:** I don't see anything wrong with that. We have always been able to do that, up to now.

**Paul Holmes:** More people would go to university. We are educating the whole population, not just the less than half who go to university.

**David Perks:** But to say that you should not educate people to a certain standard because most people do not go to university, to me, is the wrong way around. You are kind of stopping that happening by refusing to try to educate them. I go back to the beginning: in other words, if we give up on our capacity to educate the majority of young people to a certain standard in

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science—just admit it—we have given up. I do not think we should. We should strive to continue to do it.

**Q50 Paul Holmes:** So, have most western European countries given up because they do their more specialist training at university and not at school?

**David Perks:** I can't comment on other countries. It is an invalid comparison to make. The way out of a discussion about what we are doing here is always to use somewhere else. In Singapore they love studying science to a higher degree than we do, so does that make them better than us?

**Q51 Paul Holmes:** That is part of the next and final question. You have already been quite scathing about specialist science schools. In 2008, only 28% of the specialist science schools did not enter a single pupil for GCSE physics, so we are not talking about specialist schools in that sense, over the past 10 years. Should we go the way of countries such as the USA, Korea and Singapore, where they do not try to teach specialist science in every school? They have a few localised special schools to which all the budding scientists go. Or, should we be trying to teach science in all schools, and not just in a few crack specialist ones?

**Chairman:** We'll start with Peter and come back to David.

**Professor Main:** I was going to comment on the previous point. Would you like me to do that? In your previous point there was an implication that the standard of university science in this country is better than the western European standard.

**Paul Holmes:** No, we do it in three years because we have done all of our specialisation lower down the school system, perhaps distorting, therefore, the education of 100% of pupils; whereas our western European competitors do it in four or five years because they do more specialism later.

**Professor Main:** Even after four or five years, I do not think there is any evidence to suggest that our people are coming out better, nor, these days, any evidence to suggest that on entry they know any more in the specialist subjects. I really do not think that that is true. Just remind me of the second question, please?

**Paul Holmes:** Should we concentrate on a few specialist science schools, rather than having all schools trying to teach science?

**Professor Main:** No. I think that would be quite wrong. Science is too important to be left to a few specialist schools like that; I think that it should be in all schools. The biggest problem you would have with such a system would be how to choose the people to go into those specialist schools. Would people choose to go into them, or would it be on the basis of some sort of ability? The idea that it might be based on some sort of ability leads to some terrifying prospects, such as rather formal teaching of science at primary school level, which I would be very strongly opposed to. So I would fairly strongly disagree with that suggestion of specialist science schools.

**David Perks:** I think that, in a way, we are defaulting to the situation that you suggest, where there are a few state schools that are clinging on or doing well and others are giving up and going down the BTEC route, or whatever, and finding some other way to deal with this problem. If we do not do something about it, it will happen like that and there will be no way back. Personally, I am completely against that approach. I think that, if we are going to try to redress the balance, then number one, we should get rid of the equivalencies at GCSE and, number two, we should prioritise science subjects, so that they are measured, if you like, in an accountable way, and schools have to deliver science in the way that John has explained. Then you can start building on that work, using the better schools to coach the ones that are struggling to catch up. But that takes will on the part of politicians to push that through; hopefully you do want to push that through.

**Professor Holman:** I think that the idea of using expert schools to coach other ones is very much out there and it was in the recent White Paper. I think that where we have to be very clear-headed is in not necessarily equating specialist schools, as in the understood meaning of "specialist schools", with expert schools. We should be thinking about how we can identify a group of expert schools that are really good at teaching science and that can demonstrate that teaching to other schools. How can we identify those schools? Some of them might be science specialist schools, some of them might not be, but we must identify them and then put in place some mechanism by which they can transfer their expertise to other schools. They will always need support and external benchmarks, to show what really good science teaching is like; even the most expert schools will always need those outside benchmarks. That is the type of role that organisations such as the science learning centres can play, by helping schools to calibrate their expertise and to see what really good science teaching does.

**Professor Bell:** It's about bringing everybody up, not putting a few up and letting everybody else down. That is the first point. I think we are being a little narrow in our thinking today. It has just struck me, because it relates to one of the points that I made earlier, that we are treating what is happening in school almost in isolation from everything else. There are a lot of other opportunities out there related to science, teaching science and learning science. You yourself referred to the issue of universities, with education not talking to physics or whatever. What we must think about is how we can work with universities, if that is where we want students to go and if we want to give them more science. Can we facilitate that, so that there are opportunities for students not only to visit universities but to do something with universities? For example, can you do that with some of the firms and organisations around Warrington and Widnes that I know quite well? Actually, those opportunities are there. There are budding schemes that encourage some of that learning. We just don't do it in a very systematic way.

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**Q52 Chairman:** One of the earlier themes of this evidence session has been the importance of the quality of teachers, and their training and their CPD. However, I visited John's establishment in York and, John, you actually don't work with teacher training colleges, do you? You specialise in a direct relationship with schools. You don't work with the university teacher training programmes.

**Professor Holman:** We are a professional development organisation and therefore an in-service training organisation.

**Q53 Chairman:** It just seems to me that there is a missing bit of the market here. On Monday or Tuesday of next week, we will be coming out with our report on the quality of the training of teachers. I think it was said that there are about 264 places for teachers. The fact is that the quality of the professional training of teachers and how that is enhanced afterwards is critical.

**Professor Holman:** This comes back to the point we touched on at the beginning, which was that initial teacher education must not just stop at the moment the trainee teacher starts their first job. It needs to be continued and they need to be supported into their first, second and subsequent years of teaching. You mentioned the science learning centres in the next phase. This is an important role they will have, together with host institutions that are involved in initial teacher education so that people can move across the transition from the relatively sheltered world of the university to the exposed world of the school.

**Q54 Chairman:** Is the "rarely cover" situation an issue?

**Professor Holman:** "Rarely cover" is a real issue, as it is for any organisation that wants to get teachers out of schools during school time. In particular, it affects professional development. With science learning centres, some of the work goes on in schools, but most of it happens outside schools. Teachers go to the science learning centres to meet the subject experts and learn the new ideas. "Rarely cover" has made the challenge much greater. It has always been a challenge to get head teachers to understand the importance of teachers coming out of school, but it has been harder than ever this year. That has affected our ability to operate. We do not yet know whether that is because head teachers were zealous in their interpretation of the new "rarely cover" regulations at the beginning of the year, and pragmatism will set in. We are monitoring that, but we are very worried about it.

**Chairman:** The Committee will be looking at it. David, did you want to say anything?

**Q55 Mr Chaytor:** Yes, there are three or four things. Just one quick point as time is running out. Picking up on Derek's earlier point about Liverpool and the European capital of culture, is there not an argument for the European Commission to promote a new competition for a European capital of science, or is there something our Government should be doing to stimulate such a competition?

**Chairman:** You can only give one answer because there was only one question.

**Dr Oversby:** Very quickly, putting things into one target, into one place, means that the other people don't feel they have to do it.

**Mr Chaytor:** So there is no culture in Manchester because Liverpool was the European capital of culture.

**Dr Oversby:** Well, it's the emphasis, isn't it?

**Q56 Mr Chaytor:** My question really was to David. I understand exactly your argument about the focus on knowledge and content, but isn't the whole point of the new differentiations that we had that for 50 or 100 years, and it didn't really reach out beyond the most able young people? Isn't this the paradox? If you want to go back to a golden age where traditional formal content and subject knowledge reached out to the majority of—

**Chairman:** David, very briefly because the Prime Minister is waiting for us.

**David Perks:** I think you are opening a whole new discussion about the past.

**Chairman:** We can e-mail each other.

**David Perks:** The previous reform of the curriculum, which invented double science and so on, was in part to try to draw girls into doing physics and so on. That had within it the seeds of its own end because of the problems with coursework and the formulaic approach to experimental skills, to which John alluded earlier. That doesn't mean it was wrong to try to do that. You may find that you come up with something that doesn't quite work, but you have to address it again, not abandon the whole thing. The attempt to teach science academically is still valid and demands to be done. That is what we need to deal with, not just say that we had a problem last time so we'll chuck the whole lot out.

**Chairman:** Look, this has been a frustrating session in the sense that you are all so knowledgeable that we could have gone on for much longer and learned a great deal more. We want to make this brief look at STEM subjects a thorough and good one, so please remain in contact with us. We are trying to encourage colleagues to visit the science centres in universities. Of course, we visit schools and respond to invitations. This has been a very stimulating session. It has gone on a little bit later, so you can tell how interested we are in what you had to say. Thanks very much all of you.

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**Wednesday 10 February 2010**

Members present:

Mr Barry Sheerman (Chairman)

Annette Brooke  
Ms Karen Buck  
Mr David Chaytor

Paul Holmes  
Mr Graham Stuart

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**Memorandum submitted by Professor Margaret Brown**

SOME POINTS RELATING TO THE TEACHING OF MATHEMATICS

(I) *The recruitment, retention and development of mathematics teachers*

- The people teaching mathematics classes in secondary schools have a variety of academic and professional backgrounds with a variety of expertise. Some are teaching assistants or instructors without QTS, some are trained for other subjects or the primary phase or for a different national system, some (eg those from Teach First, GTP) may have degrees in mathematics, related subjects or quite often non-related subjects, and have undergone a brief generic training but had little or no guidance or discussion about how to teach mathematics. Teachers need both a deep and connected understanding of the mathematics they are teaching, where it leads and how it is used (not guaranteed by a degree in mathematics) and a deep understanding of how children learn and how each topic can best be taught, including available resources. Educators from other countries are amazed by the lack of training and qualifications required to teach mathematics in England. Unfortunately there is very little valid information about the existing mathematics teaching force; surveys which do exist (eg by NFER) do not do justice to this variety, and schools will go to some lengths not to reveal shortcomings in case they affect pupil recruitment. *We need to collect more detailed and valid data about the current mathematics teaching force so as to plan professional development to bring the knowledge and competence of all those teaching mathematics to an acceptable minimum, using courses such as the successful Mathematics Development Programme for Teachers.*
- There is no simple relationship between qualifications and teaching effectiveness—some less mathematically qualified and/or less well-trained people who are intelligent, reflective and resourceful can develop considerable expertise, whereas some teachers with maths PhDs and a full PGCE fail to progress beyond adequate. Nevertheless heads of mathematics departments express clear preferences for a maths degree and a PGCE, both from a good university. Many people on PGCE courses (including the OU PGCE) have both excellent mathematical qualifications and several years of experience in other careers; other routes are unnecessary as long as enough funding is available, and courses are available for teachers already in post. Our best schools can attract a full team of PGCE-trained teachers with good mathematical backgrounds; the problem is that those new entrants via eg Teach First or GTP who receive little training in how to teach mathematics and/or have weaker subject backgrounds end up in the poorer schools where they are much less likely to experience good practice or stimulating mentors. *We should remove routes into mathematics teaching which either have little time devoted to developing deep understanding of mathematics and how to teach it, or accept people with weak mathematical backgrounds with little additional support. Two year PGCEs should be expanded (or at the very least the six-month Mathematical Enhancement courses should be available in all areas and part-time via the OU) to prepare those with weaker mathematical backgrounds to enter a PGCE.*
- Mathematics teachers unsupported in weaker departments are most likely to leave the profession. Even in strong departments, future Heads of department will benefit from sustained external opportunities for development. The National Centre for Excellence in Teaching Mathematics is doing a good job of supporting teachers via the internet and occasional one-off meetings. *However, for retention and for development all teachers need ready access to a local network and to well-funded external and sustained support and stimulation such as Masters degrees, or curriculum development groups provided by some combination of LA, HE and other agencies. It is not clear that MTL courses will always have sufficient subject-specific content.*

(II) *The mathematics curriculum and the adequacy of recent attempts to improve mathematics teaching in schools*

- Mathematical standards overall have not risen in 30 years and there are more very low attaining students now than previously. The “raising standards” agenda is depressing both the real standards of mathematical competence and the attitudes of students to mathematics. Currently the teaching of mathematics in schools is dominated by the perceived need to get as many children as possible to a grade C in GCSE to raise the “five GCSEs including maths and English” percentage for the school. Since GCSE English results are generally higher than maths, there is huge pressure on

- maths teachers. This has led to practices such as early GCSE entry and frequent re-takes (one awarding body reported Autumn entries up by a factor of 10), with constant coaching on exam questions for students who do not understand the basic ideas. As at A-level the re-take situation will get worse with more modular GCSEs. Examining costs are increasing at the cost of teaching expenditure. The time after early entry is rarely well-used. The needs of the most and least able are often ignored and the best teachers assigned to the classes predicted to be borderline C/D. Ofsted and the National Strategy have deplored the inappropriate early entry but heads are pressurised by “school improvement” advisors. *To improve teaching and attitudes, the target and league table pressure needs to be removed to allow the curriculum to be determined by the student’s needs and not the school’s.*
- Over-specification by the Secondary National Strategy Framework and over-emphasis on “pace” in curriculum and teaching has led to fragmented teaching which moves constantly from one procedure to the next, with most students having failed to consolidate basic ideas and left without time to grasp anything firmly enough to remember it. We are often building on sand. The framework has led to poor textbooks and Interactive White Board software, didactic teaching styles, and negative attitudes among both teachers and students. This prevailing situation makes it difficult to retain teachers. But improvement may be coming: the Strategies are winding down, there is a focus on assessing pupil progress (APP) and assessment for learning (AfL) so teachers may importantly become more aware of gaps in understanding, and the new national curricula (and to a lesser extent the new GCSEs) include more problem-solving and mathematical processes. The matched pair of GCSEs are being piloted soon. But there is virtually no evidence that these changes are having any effect in schools, and indeed they may not have; many teachers don’t understand the changes, awarding bodies are reluctant to assess them, and there are few appropriate resources. Teachers’ understanding of and planning for progression in the understanding of key mathematical content is also at risk with a process-focused national curriculum. And it is not clear that students will become more functional in mathematics. *Curriculum and assessment development and implementation processes are dysfunctional and need re-thinking: teachers and other stake-holders need to have more input and control, and more time, training and resources are then needed to achieve desirable shifts in the curriculum and teaching.*
  - Having three different examination boards run by organisations which also sponsor or produce textbooks, leads to competing for custom on the basis of making it easier to achieve “good” grades with inadequate learning and inadequate teaching. The way GCSE papers and questions are structured does not help to raise standards, nor, as stated earlier, does the introduction of modular GCSEs. *A single national system of assessment (as with national curriculum tests) which is under greater democratic control, may be more effective than the current situation where some awarding bodies have significant interests in resource provision.*

(II/III) *Engineering education/Vocational provision in engineering: mathematical aspects*

- Mathematical literacy is essential for most engineering skills at all levels: this includes geometrical as well as numerical and algebraic fluency, and must incorporate the understanding which underpins skilled use of recent and future software. We need continually updated analysis of what this means for the mathematics curriculum—both core and specialist—at all levels. *The current school curriculum in mathematics at GCSE and A-level is in need of updating to serve the needs of engineering and other key fields like finance/economics, medicine, etc. This is a significant undertaking, with knowledge transfer and convincing of stakeholders even more difficult than the initial research.*
- Engineering course designers (eg for the Engineering Diploma) often underestimate the time and varied experiences that are needed for students to master the mathematics required for engineering skills. Too much time in the Diploma is given to knowledge about engineering rather than knowledge for engineering. *A significant time must be allowed in vocational engineering (and other) courses for the learning of the underpinning mathematics, to cover understanding, skills and application.*
- The teaching of mathematics for engineering, requires a thorough understanding of engineering principles and applications, connected knowledge of the mathematical ideas, and knowledge about the teaching and learning of mathematics. Who does the teaching is less important. *Successful teaching of mathematics for engineering requires collaboration between teachers of mathematics and engineering, which takes time.*

*Witnesses:* **Professor Margaret Brown**, Professor of Mathematics Education, King's College London, **Dr Tony Gardiner**, Reader in Mathematics and Mathematics Education, University of Birmingham, and **Jane Imrie**, Deputy Director, National Centre for Excellence in the Teaching of Mathematics (NCETM), gave evidence.

**Q57 Chairman:** I welcome Professor Margaret Brown, Dr Tony Gardiner and Jane Imrie to our deliberations. We are always grateful to you for coming. We can actually make you come, but we don't like doing that. There have been only one or two occasions since I've been Chairman when we have had to threaten to send the Serjeant at Arms to collect someone, but it has never been necessary. It is good that you are here and we value your expertise and experience. In this Committee, we tend not to use titles after the initial introduction and go on to first name terms. Is that acceptable? It improves the flow. You can call us anything you like—but you call me Chairman. You know why we are here. We are looking at the teaching of STEM subjects. Since the Committee has had its new remit of children, schools and families, on the schools side we have had major inquiries into testing and assessment, the national curriculum and school accountability, and we finished it off with a report on the training of teachers, which was published yesterday and has been reasonably well received. Today, we are looking at STEM subjects and their teaching. We tend to give our witnesses the chance to say who they are and what they think the problem is with the teaching of STEM subjects, but we try to get them to put it in a nutshell and not go on for too long, because we want a lot of evidence this morning. Margaret, would you like to start?

**Professor Brown:** I have circulated a longer statement, but I am just going to pick up two points. Speaking as a researcher, they both draw on projects that we have done and on our information. The first one is what makes an effective teacher of maths, in the quite narrow sense of getting good average gains for your class between the beginning and the end. Our results on that are that teachers have to have a connected knowledge of mathematics. It is not enough to be able to control the class and stand up and instruct. You have to have a connected knowledge of mathematics—how to apply it, how to teach it and how students learn. When we inquired how they acquired this knowledge, we found it was through experiences that had three contributing factors. One was time; it had to be something that had taken place over time. It had to be something where there was expertise and leadership, so that there was somebody there who could provide you with assistance. There had to be opportunities for discussion and talk, too. I think we have to judge our paths to teacher training by those criteria. If there isn't an opportunity for time, talk and expertise related to the teaching and learning of mathematics—I have to make it clear that this is about mathematics—then these are likely to fail. The same goes for our effective CPD. We have to look at how teachers can get local networks that can support them in long-term, expert-led CPD. The second point is about standards and the quality of teaching. Some of our recent research suggests that standards in mathematics have not changed over 30 years, and yet the test and exam results have gone up

inexorably. This suggests either that the standards have slipped—have dumbed down—or that the teachers are very expert at coaching, and it is probably both. So we have to remove the factors in the situation that contribute to this. The competition between examining bodies to make exams ever simpler, with more and more modules that make sure they are fail-safe, is one problem. They compete on how easy it is. Another point is that there is not only constant coaching for exams but early entry, so there is a big push to get students doing more and more maths earlier and earlier. That leads to very superficial teaching that is very fragmented and procedural, which leads to bad attitudes among students and teachers, not knowledge that endures and can be used in STEM or in other areas. We have to release some of this pressure. Students need time, talk and expert teachers to learn mathematics, just as our teachers need that. We have some good initiatives going, we have a good new curriculum, we have better GCSEs coming up, and we have good initiatives on assessment for learning, but nothing is happening in schools because there is still this enormous pressure to get exam results up in maths. Until we release that, I don't think we will really take advantage of the good things that are beginning to happen.

**Chairman:** Thank you.

**Dr Gardiner:** Yesterday I had a very sobering day with 350 year 10s and year 11s, which brought today into a certain focus. You've really got to decide—as the numeracy and literacy strategies had to—what the first, second, third and fourth letters of STEM are. I suggest that it be spelled MMMM. That is not because I am biased in favour of mathematics. I think that just as you have to learn your mother tongue before you can do anything else, if I were a scientist, engineer or economist, I think it is obvious that I would want to get the mathematics sorted first. The idea that there are four letters and so they all get 25% seems educationally crazy. Mathematics is very basic. Which brings one to the question: what is mathematics at school level? We have not got it sorted. Partly because of the attempt to impose accountability, which Margaret alluded to, and driven by results, we have changed mathematics education into a processing factory; to see what is coming out, I referred to the 350 kids I met yesterday; they were all so-called A-A\* material for GCSE, and they mostly had not been learning elementary mathematics—they had been preparing for exams, and there is a completely different outcome. Somehow, the point that Margaret alluded to needs to be addressed. It is almost a bigger point than your Committee can address in the time available, but the whole attempt to unitise or modularise GCSEs is a disease. It is clear that modular exams were introduced to try to cater for those who found end-of-course exams too much to chew on and who might give up at A-level. They were called the new sixth form; they needed something, but there wasn't an alternative

qualification and they had to do A-levels, so A-levels were made more palatable. If it is a terminal course, I do not see anything wrong with a modular structure—if students are going to stop, and what you've done is tempt more people to do more than they would have done; but making it a national measure and moving it down to a unitised version at GCSE has had all the effects that Margaret has alluded to. All these kids were being pushed to take GCSE modules early on the stupid grounds that they could get things wrong and have another go. Well, in mathematics, once you get something wrong, you have a feeling down here in your stomach about it, which many adults know, and it stays with you. In mathematics, the idea ought to be, "Get it right first time, be patient and take it when you're on top of it." So my point is about modular structures and how they change what mathematics is. As for teacher training, we have two serious problems. I don't think that a masters in teaching and learning is the answer. I think your report highlights the idea, in paragraph 99, that initial teacher training is only a beginning. I think that would characterise most successful countries. The TDA threw that out when it drafted the initial teacher training national curriculum in 1998. It was a recommendation of the people involved that initial teacher training should not stop after your PGCE, but that there should be another three or so years in which you clear up the deficits that you might still have. Those deficits are subject-centred and subject-teaching centred. The MTL is generalist, and I encourage you to notice that the institutions that you might put at the top of your pecking order don't seem to be involved in the MTL consortia. As far as I can see, Oxford, Cambridge, Warwick, King's and the institute are not involved; is that correct?

**Professor Brown:** We are starting—all those institutions.

**Dr Gardiner:** So there is a problem there. We've got down to a system that is going to be pushed through, using providers that might not be your first choice providers. We've got to get subject-centred stuff in there. It will take time. It has to go beyond initial teacher training, but we also have to recognise how bad the situation is. Margaret is too nice to say it in the same language, but many—no, most—Key Stage 3 teachers have a very weak grasp of elementary mathematics. I recommend that you read "Mathematics: understanding the score", Ofsted 2008, which says that in most uncharacteristic language; for some reason, that has not been picked up.

**Q58 Chairman:** Do you agree with Margaret that the examination boards are also at fault?

**Dr Gardiner:** I think that the examination boards are given a framework and they work to that. The examination boards used to work reasonably well, after a fashion. They have now been put in competition with each other and have been given ground rules that force a kind of *reductio ad absurdum*, or a lowest common denominator, so I

wouldn't blame the exam boards. The QCDA has to take the rap, but there is a background issue, which needs to be addressed.

**Chairman:** Tony, thank you very much for that. Jane?

**Jane Imrie:** The NCETM, as you know, was established four years ago particularly to focus on the CPD of mathematics teachers. Reading the *Training of Teachers* report yesterday, I was particularly pleased to see the notion of ITE and CPD being a continuum. ITE is only the start, although we have concerns about the amount of subject-specific elements in initial teacher education. Margaret spoke about them very eloquently, so I will not repeat what she said. On the notion of teacher education and development as a career-long process, and developing a learning profession, a vital aspect of that is, to quote the report, teachers reflecting on their own practice. I think that one of the issues for us is that we perceive, even with the best teachers, a gap between how teachers believe they want to teach and how they feel they are allowed to teach. A lot of that has been through centrally controlled CPD and training, rather than training coming from the needs of the teachers and their learners. I would like to say at this point that as well as CPD being subject-specific, which is crucially important,—there is a lot of research that suggests that working on mathematics not only makes it more meaningful for teachers, but has a greater impact on their work with their learners,—sorry, I have lost my second point. I will come back to it. One of the recent initiatives that the centre is really pleased about is the MaST maths specialist teacher programme in primary. We were very pleased that all the recommendations from the Williams review were accepted. However, we are now concerned about all the other teachers in primary, all of whom teach mathematics, and want to look at what sort of professional development and training is available for them. On a particular point about mathematics, Tony alluded to STEM being spelled MMMM. I actually think that mathematics is much bigger than STEM in so many ways. STEM could not be there without mathematics, but mathematics could be there without STEM. Mathematics is unique in being a cradle-to-grave subject. We make sense of the world mathematically from the moment we are born, even if we do not articulate that in equations. So working with primary and early years teachers is as important, in terms of enabling progression as working through all phases and enabling cross-phase working—this also comes through in yesterday's report—and harmonising training, cross-phase, we have a lot of evidence now that this will have quite an impact on progression within mathematics. That is another important aspect of our work. The report alludes to entry requirements for training. I think we should demand greater confidence in mathematics among all entrants to teacher training, as the report suggests. Evidence suggests that they relay their anxieties and beliefs to students, even if they are not directly teaching the subject. Equally, teachers of mathematics need greater confidence and a deeper subject knowledge. Some of that should be there on

entry—we need to work very hard on that in initial teacher education—and there need to be opportunities throughout their career to work on mathematics. Teachers need to be learning mathematics throughout their career to understand how mathematics is learned. There is also a debate to be had about the level of degree that teachers need on entry. I am not sure there is a direct correlation between having a first-class degree or a 2:1 and being a good teacher. There are too many variables. A deep subject knowledge is essential, as are enthusiasm for the subject and the ability to communicate it, good pedagogical skills, understanding how children learn and embedding that in practice. Not one of them can be taken in isolation. To suggest that one should be stronger than the other would be a mistake. Perhaps there is some work to be done to identify what the appropriate entry requirements are.

**Q59 Chairman:** We thought that a 2:2 should be an entry point.

**Jane Imrie:** Yes, possibly. It is rather like setting the entry requirements for A-level and then discovering that, somewhere along the line, somebody did not unlock a student's potential. If you give them a chance, you unlock their potential. I have worked with some very good teachers who had third-class degrees, but had opportunities in their career to develop their practice. I think that is the important thing. We currently have a culture where your training stops when you have done your NQT year and there aren't the opportunities. My final point is that the opportunities are more than courses. One of the things that the NCETM focuses on is developing communities of practice, through teacher inquiry, regional activity, working with higher education institutions and local authorities; teachers working together, talking together, and sharing what they are doing is a crucially important part of CPD.

**Q60 Chairman:** I am glad that you all seem to have read our report and that there is mild approval for it. May I just ask you one question before we drill down. In the previous session on this subject, I asked the panel whether any work had been done on what makes a child prone to be good at maths, or good at science. Has any work been done on the development of a child's brain and aptitudes? They seemed to be a little astounded that I had asked that question, but one's life experience suggests that there are children who, very early on, have very different abilities, especially in terms of maths. Tony, you are immediately shaking your head. Is there any research about how you—I mean, there is a lot of research and we have some highly-qualified advisers to the Committee on early years, including people such as Kathy Sylva. There is a lot of evidence about early year stimulation being very important. Is there any secret locked here?

**Dr Gardiner:** I think it is a dead end, which one cannot resist playing with. Clearly, we all know some people who stand out in a way that is sufficiently breathtaking to justify the question. But there is something that makes the difference and it is called a good teacher. You are not going to create an Einstein

with a good teacher, but I know teachers who take bottom sets and get them A\*s and people wanting to go on and do more mathematics. The whole essence of teaching is that you can change what is in front of you, you can bring out the best of what is in front of you. I was leader of the international Olympiad team, I have worked with many of the best mathematicians in the UK for many years and I say it is a dead end. There is clearly something there, but it is not part of the educational policy domain. You have got to think, how do you get everybody up to a decent level and not, can we pick out a few five-year-olds and put them in a special school. That is exactly the wrong thing to do, because even if you can pick out—I mean, look at Singapore. I have been consultant to their gifted education programme. They used to pick out people at the age of eight and put them in special streams in special schools and they have sort of given it up because they found the others did better in the end. Certainly, it is worth thinking how to provide for those who stand out, but the pub talk mentality, or the cocktail party mentality, is wrong. You really want to think how to take people who are moderately decent and make them a lot better. That ought to be the whole thrust of policy.

**Q61 Chairman:** Have our gifted and talented programmes over the past eight or nine years helped?

**Dr Gardiner:** It has been absolutely disastrous. As far as I can see, nothing was produced that was of any use to teachers, no guidance that was of any use to them, and all they have extracted is the idea of early entry, which is destructive. In mathematics, you want to get on top of things and get them right. You want to know that you can get 100%. You don't want to say, I am clever so I can get a B at age 12. That does not lead to somebody who wants to go on to do A-level. I am called out all the time. I have a year 1 student who is entered for A-level this year. It's scary and it doesn't lead to a good 18-year-old.

**Q62 Chairman:** Margaret and Jane, do you agree with that about gifted and talented programmes?

**Professor Brown:** Yes, absolutely. Some very strange things have been happening in schools on gifted and talented, where you take the top 10% in something or other, but there has not been a lot of good mathematics as part of those programmes at all. There is certainly no effect on mathematical achievement, or mathematical take-up, or mathematical interest that is traceable to any of those programmes.

**Q63 Chairman:** It's a lot of taxpayers' money we're talking about. Jane?

**Jane Imrie:** I would agree. It comes down to what Tony said about good teachers. The good teachers will make the most of any programme that is presented to them. Equally, there is a lot of evidence concerning teachers' beliefs. If teachers label students and decide early on that they can't, then they won't. If teachers decide they can, then they

will, so the notion of singling out a group and suggesting that they can and will and the others might not, I think is an issue. So I would agree, yes.

**Q64 Chairman:** Tony, so why can't we clone good teachers? Why can't we clone them through the internet? Why do we need teachers? Can't we do it all through IT and kids logging in? Can't we get high-quality instruction and stimulation that bypass modest teaching capacity in the school?

**Dr Gardiner:** Well, you could if the human element were irrelevant. You could do it with an avatar figure. In fact, the human blood, the arm round the shoulder, the clip round the ear in the old-fashioned sense, matters. Somebody who knows how to use their voice. I am a very bad teacher. Somebody who knows how to use their voice so that a kid wakes up and realises, "Hey, I'd better not do that." You can't do that at a distance. The teacher is crucial. Why can't we clone them? We don't have very good agreement or understanding of what a good teacher is, what they are doing. There are disagreements as to the importance of the subject matter. I would urge caution—I don't know who can exercise it—about third-class degrees. I run a lot of things for teachers—perhaps not as many as Margaret does. There is a large group of really wonderful teachers who went to university where, one could say, they had a good time or found the stratospheric level not to their taste, but they love elementary mathematics and love kids. They got thirds and are now fantastic teachers. I ran a course for third years last year and the best kid in the class by a mile got a third, because he wouldn't play the system. I hope he will now be in teaching.

**Q65 Chairman:** You wouldn't allow him into medicine on the same basis, would you?

**Dr Gardiner:** I think you would. By all means have a level, which is normal, and require some exceptional presentation of evidence for anybody below that level. The idea that you exclude people from university because they haven't got A-levels—we don't do that. We look and see what else they have done. By all means, set a level, which is the norm. It is the same for university entrance—two As and a B for Birmingham—but if you get an A and two Bs we look at you to see if there is some reason why you should come in. It would be silly just to say no thirds.

**Professor Brown:** And it does depend on which university you went to, to put an obvious point. To get a third at Cambridge you must have had very high results at some stage in your career, to have shown that you understand the mathematics at that stage. Understanding the mathematics at that stage is probably quite enough to be a good teacher. We take people with good degrees from different universities and there is not a huge correlation. To decide whether to accept them as a teacher, we set a GCSE question and ask them to do it and then to explain it, as they would to a class of children. We find that many people with good degrees can't even do the GCSE question let alone explain it in any

terms you could understand. Whatever is going on in many maths degrees it is not related to the mathematics you need to teach in schools.

**Chairman:** Is it related to the so-called good universities? I find some of the worst people I have ever employed in my office had firsts from Oxford and Cambridge. Perhaps that is sharing prejudices. We are going to move on. I have warmed you up. That is my job as Chair. Karen.

**Q66 Ms Buck:** I may be being unfair—and I hate to be unfair—but I sense a little bit more analysis of the problem than recipe for a solution. I wonder whether we can tease something out with teacher training. We heard from Margaret and our advisers earlier that this is an issue that has been extant for three decades at least. Our relative performance internationally on maths has been weaker than in other areas. This is not a new phenomenon. Picking up on Tony's point about modular teaching, our problem in maths teaching and recruitment into teaching, clearly predates a shift towards the more modular approach to maths in schools. Was there a golden age? Was there something we were doing right decades ago that we are not doing now?

**Professor Brown:** I don't think there was a golden age. I think we need to get rid of that notion. There are changes in circumstances. The modular effect has changed the quality of teaching. If you look at the Edexcel website, you will find that the new GCSEs in maths are advertised as, "This provides bite-sized chunks with clear, straightforward questions." That means easy, but they are not allowed to say easy so they use words such as clear and straightforward. It is about breaking up maths into lots of little bits. You learn a bit one day, and you get tested on it and then you can forget it. That is a new phenomenon. It has come into A-levels in the last five years. It is a damaging practice at the level of teaching, which we did not have before. You are right to say that we have always had the problem of attracting good teachers into maths, and that is because we do not produce enough mathematicians with university degrees, and there are now far more better paid attractive jobs that mathematicians can get. We have always had that feature, certainly since just before or after the war when teaching was the only thing that people with a maths degree could do.

**Dr Gardiner:** I think you are being a little unfair. You ain't seen nothing yet. The modular disease is relatively recent, and will affect those going into teaching in five years' time or now. We predict that it will get worse. The bitty view of the subject will be awful. I do not think that you can say that we have always had the problem. Have I got a problem with giving up alcohol? No, I don't try. We never tried to recruit maths teachers. The number of maths undergraduates remained stagnant for about 30 years, at about 3,500 to 4,000. It has now expanded slightly. We have never tried to target mathematics undergraduates to get them into teaching. People were quite happy with the fact that there were bums on seats. We moved the PE or the history teacher sideways; there was no quality control.

**Q67 Ms Buck:** Were they happy?

**Dr Gardiner:** Who were happy?

**Ms Buck:** Well, whoever—head teachers, governments or successive governments. Or was it that they were shuffling the pack?

**Dr Gardiner:** I don't think that head teachers, any more than politicians or civil servants, understand how difficult maths teaching is. It is a fog to them, and they are quite happy to leave it on the side, and not think about it. When Ofsted wrote in 2008 in *Understanding the Score* how weak Key Stage 3 maths teaching was, there should have been blushes all round, but there weren't. TDA has gone on with the MTL in exactly the opposite direction from what that report suggested. Mathematics is a fog and people prefer not to look at it.

**Jane Imrie:** The point about heads and school improvement partners and others being non-specialist is really important, because they do not know the solutions. They might identify the problem, but they would need very subject specific knowledge to understand the solutions. The nature of maths is such that you can just pare it down to content and very mechanistic approaches to pass exams, which is what my colleagues were alluding to. That is a bit like spending a music lesson just playing scales and never actually hearing any music, and therefore not getting any appreciation or understanding of the music itself. I agree with Margaret, there is not a golden age as such, but what we have lost is the embedding of teacher development within initiatives, and so we tend to start initiatives—functional skills is a good example—by thinking of the standards, the assessment and what we would like to see happen and, at the very end, bringing in teacher development. There are good examples in the recent and distant past in which development has happened with teachers alongside. So we need to ensure that everything happens at once—teacher development, what we want to achieve, how it happens and how we assess it. They are much more successful qualifications because the people working on them have a really good understanding of what can be achieved. It is good professional development as well.

**Q68 Ms Buck:** Certainly, the advisers were telling us about the relative performance in maths in this country compared with our international comparators, and that is a long-term issue. What is it that they are doing right, particularly in terms of getting people into high quality teaching? Or is it a chicken and egg situation? If you teach maths better you will get more people going to university.

**Dr Gardiner:** You have to be more critical about your statement. The TIMSS results at year five in 2007 were rather impressive, and an awful lot of work over the previous decade went into the numeracy strategy. I think you have to look and say, "Is that apparent improvement in year 5 of a kind that leads to long-term improvement?" We don't want improvement at year 5; we want improvement at year 12. We want the output at age 18 to be better positioned. I think the improvement at year 9 is

incredibly weak, given the effort that has gone in. We are back roughly where we were in 1995 in year 9. A lot has gone into primary schools and there has been an improvement in some measures, but I do not think that they are teaching mathematics—they are teaching tricks and little rules that are short-term gains. I do not think that feeds through to Key Stages 3 and 4. That is my judgment; we will not know for a while. TIMSS is not very useful now, because of its allowing calculators. It does not tell you what it used to tell you. There is a weakness. What do other countries do? They have a more standard approach to training, but it is not just training—the curriculum makes sense. I disagree radically with Margaret's comment. The 2007 national curriculum is just vacuous—there's nothing there any more, so I disagree radically on that. If you look at it, you will see that there is no content. The words that are there don't mean anything to me, and I can't see how they can mean anything to anyone else.

**Q69 Ms Buck:** I am trying to push you a little bit on what it specifically is that comparative countries are doing.

**Dr Gardiner:** They sort out what they want delivered. They make choices. We have made the mistake for 20 years of trying to please too many people by putting too many things in. They give time and they train teachers to deliver what is there, and they give them the freedom to use their initiative and to not feel constrained. There are important exams in some of these countries, but they are not as distorting as the current English regime. I am afraid that they do rather a lot of things differently.

**Professor Brown:** I am not sure that I totally agree. I am not sure that the quality of teaching is higher anywhere else. Some of the countries that do extremely well have an even more kind of procedural teaching than us. Maths is more high-status as a subject than it is in England and teachers spend more time on it, but if you research what goes on in classrooms, I am not sure that it is necessarily wonderfully better. I think we have to use our own criteria, as well as others. Obviously, we look elsewhere to see what people are doing, but we should not assume that, because they do well on TIMSS, the quality of teaching is high.

**Ms Buck:** Okay, so radically different views from our expert witnesses.

**Jane Imrie:** Coming back closer to home, there is evidence from learners that the perception they are getting of what mathematics is—this has come through QCA work and my own experience in talking to learners—is that it is about the next test, the next hoop and the next module, rather than an understanding of mathematics. Colleagues in HEI, in the recent research that More Maths Grads did, perceive the same view of mathematics coming through from undergraduates. They do not really understand what mathematics teaching is about, therefore why would they see it as a profession? Anecdotally, I know that excellent teachers who

really draw out mathematics in the classroom have a pretty good success rate of getting some students going into teaching.

**Q70 Ms Buck:** May I just ask one last cluster of related questions. It is hard even to attract the mathematicians that we have into teaching, but let us set the quality issue aside for the moment. Some of the prescriptions that are being suggested, particularly by Margaret, and some of your critique of how to improve standards, require people to undertake potentially longer courses and possible employment-based training. How do we encourage people to take additional and more in-depth training when we are having difficulty recruiting in the first place? What are the mechanisms with which we can resolve that problem?

**Professor Brown:** In many cases, people actually want to do more training. The problem is fitting it in. There is a huge amount of pressure on maths teachers in schools to be in front of classes. We have many occasions where people simply cannot get out of schools because heads will not release them. That is one problem. We had somebody who applied for a PhD and their head offered them an extra £10,000 to stay in the school. People do want to do more training but the pressure on schools to achieve in maths is very high. Sometimes that actually counters the desire of teachers to do it. The other point is that much of our professional development can be done around things that are important to schools. There are things such as masters degrees that are important to teachers and their own professional development, but producing materials for curricula for teaching is a very good professional development activity, if it is done long-term by appropriate people who understand what they are up to. We can do things that are immediately useful for teachers, which will also become good professional development. There is a real problem about finding time. Teachers with families find it difficult to do Saturdays; they find it difficult to do after school. Head teachers won't release maths teachers during school. It is very hard to see how to organise these activities.

**Q71 Ms Buck:** Presumably, we need to spend a lot of money training people, extending people's training when they don't have to be at work and not losing staff.

**Professor Brown:** I think so. That is part of it. You have to be creative. In some cases, people can do weekends. Williams courses are run partly on weekends and partly in holidays, and some teachers can do that. Those are going very well. Though there are some teachers who find that difficult. It is about trying to be creative about the best ways of doing it.

**Chairman:** A very quick one, as we have to press on. Tony and then Jane, but quickly.

**Dr Gardiner:** I think we can do things. I don't think we are necessarily having difficulty. I don't think we are trying. I run a third-year course where kids are queuing up to do a maths teaching module. They start very weak but they turn into remarkably impressive people. In contrast, there are other areas like the national mathematics teachers' summer

school, which is the best thing I have ever done, where we can't recruit. You have to look and see where the opportunities are and go for that. That probably means not big centralised plans but something that releases initiative.

**Chairman:** Jane?

**Jane Imrie:** I have a similar point. I was going to pick up on what you said about putting lots of money in. There are creative solutions in the best schools. There are simple solutions, such as having extra people in the team so that staff can be released to do things, or working well with appropriate support. There are things but it is about allowing that creativity and initiative to happen. Picking up an earlier point, making the profession more attractive—and it's in your report—is about professionalising the work force and prospective teachers recognising that they are coming into a profession, which is career-long and has progression and development.

**Q72 Mr Stuart:** Let me return to the subject of qualifications for going into teaching. I think all of you seemed to suggest that some people who got a third-class degree, depending on the institution and all the rest of it, might do a good job. Yet, the aim and hope and the reason it is in our report is the recognition that there are a lot of people entering teaching who take numeracy tests multiple times before they go in. They are probably not going to be excellent and don't have the subject grounding. Perhaps you could finesse what you said earlier. There will be a new Government—of whatever sort—probably in May. How should they deal with this, so that they increase the rigour and raise the bar, without creating absurd cut-offs, which stop people for whom special cases can be made, as Tony put it earlier?

**Dr Gardiner:** I am not sure they are special cases. Margaret pointed out the fact that some people with thirds, if they get into certain institutions, have mastered mathematics up to age 18 rather well. You have to lay down rules that allow for that. I am not convinced that people who repeatedly fail numeracy tests are necessarily those getting thirds from Birmingham, for example.

**Q73 Mr Stuart:** So that we don't just have an analysis of the problem or the problem of the next policy wave, I'll repeat the question. I am Conservative and the party seems to be saying that we are going to set this bar. How do we raise the bar in an appropriate way?

**Dr Gardiner:** I see nothing wrong with setting the bar at a higher level and allowing exceptions who have to show more than the others—they have to demonstrate that, although they are below the bar, they have more than the others, so you put more effort into allowing them through. That's fine, but it would be a mistake to assume that people who have a first from Birmingham will not fall down on these tests. I think you want to kick universities. I think universities should have their undergraduates sampled so, for all subjects that might lead into mathematics teaching, the students are sampled with

year-9-type problems—TIMSS problems. See what they can do. The universities should be made to realise that they are letting people through. Do it on a sampling basis so you're not targeting individuals. I think that the universities would get a shock. I give our third years TIMSS year 9 problems and they can't do them. Half of my third-year class fail year 9 problems. One could do a very simple quiet kick nationally, and it would be cheap.

**Professor Brown:** Can I come back to the numeracy tests. They are mainly failed by primary teachers or teachers of subjects other than maths, and actually they're irrelevant. We ought, first of all, to try to raise the bar at the beginning of a primary teacher education course—mostly a PGCE. What we miss from the longer courses, when primary teachers trained for three or four years, is that then there was time to turn people who had quite weak maths into quite confident people who basically had a deep understanding of maths. I think that we have to take action because most of the primary training has gone to PGCE, and there's very little time in a PGCE course for maths. We're getting people through into teaching, and you see it in the classrooms, who know very little about maths as primary teachers. What we are doing is right. We're doing the Williams-type training for one person in each school, and hopefully it will spread to all schools, and then there has to be work in the schools to bring the other teachers on. We have created a problem in primary by cutting our courses from three or four years to only one year. I still think that we can get people, even if they do not start at a very high level, to a sufficient level of understanding in maths, by putting in the time and the expertise for them. We simply have to do that because we have to take the situation as it is and up those levels of expertise.

**Q74 Mr Stuart:** Are we able to do that? There is another teaching gap. Is it just about course structure? Do we have the personnel and the expertise?

**Professor Brown:** There are some gaps in the system. One gap is at local authority level. We used to have things called maths advisers. A maths adviser was someone who had been a head of department in a secondary school for many years—a very talented, good teacher—who then often did a masters degree and was very solid. In some areas, we still have excellent maths advisers, but that tends to be in the big counties such as Hampshire and so on. In many places, you simply have a strategy consultant who's not paid very much, given a temporary job, pulled out of school and is probably not as good as half the people she or he is supposed to be supporting. We have to go back to making a career structure where we have things called maths advisers who can act at the local level, assist teachers in the schools and make links nationally and with HE. I think that that is the big gap in the system at the moment. We had a stronger situation in the past.

**Q75 Mr Stuart:** You have touched on it already, but we've had criticism that there is not enough subject-based content in the MTL. If you were a head

teacher, what would you be looking for from courses for a young teacher to develop their subject knowledge?

**Professor Brown:** I think you have to be a bit careful about head teachers, because they are often under pressure to implement the latest thing. A lot of the training has to happen in schools, and heads know sometimes that it isn't very effective. For example, if Assessment for Learning is the latest thing, we have one day on Assessment for Learning. There is an agenda being driven that way. Now, that is absolutely counter to what we know about teacher development which, as I say, is about time and expertise. What we need to work on is the time to develop in a Masters in Teaching and Learning. People need to know about the research that has been done about maths. They need to have a deeper understanding of their own mathematics education. They need to have a deeper understanding of their own maths and they need to have time to think about it and consider how it is used in different professions—how people use it outside. There is a huge amount of maths-related stuff that can be put in a masters degree. We do very good masters degrees, I have to say, in mathematics education. We do not have enough people doing it. We have about 20 a year, and it is all focused on maths. There is a little on middle management to help them become heads of department if they want to do that with this national assessment, but it is very focused. Our concern is that people are given what appears to be an equivalent MTL qualification on much more low-level stuff. Frankly, some that I have seen around is what you might do in the first year of an undergraduate education course. It is really very low-level. Our concern is that a masters degree should be M-level—a masters level course.

**Q76 Mr Stuart:** Where have you seen this first year undergraduate-level course?

**Professor Brown:** I have come across a graduate from one. We foolishly—

**Mr Stuart:** Where?

**Professor Brown:** I am not prepared to say where, if you don't mind. It was actually quite a respected institution. During that time, she had had no supervisor or tutor with an expertise in maths. She was a maths teacher with a masters that was similar to, and had the same criteria as, a Masters in Teaching and Learning. She had no great understanding of the research literature in maths, because she had been tutored by a sociologist, or what have you. She had no great idea about what was going on: the new initiatives in maths education, assessment theory or anything like that. I am not suggesting that we have to be in an ivory tower and learn all about theory, but you need a deep understanding of these things. You need to think about what is behind them, what we know about what is behind them and how to conceptualise these things. Doing a little project about your teaching doesn't always bring that in.

**Chairman:** Graham, last question. We've got to move on.

**Mr Stuart:** Tony wanted to come and then I was going to challenge Jane on what the national centre is doing to change things.

**Chairman:** Tony come in briefly and then Jane. Then I am going to switch to Paul, because we are running out of time.

**Dr Gardiner:** Margaret made the point about old-fashioned BEds and PGCEs. In a BEd, you have three or four years. You can engage slowly and improve people. One of the major things that is needed in the early years of teaching is not general MTL masters-level stuff, it is a craft learning of your subject, which they have not had in school and university. They have to engage with elementary mathematics, they need time for it. There are examples of this: the Teaching Applied Mathematics (TAM) course, where they took people who had not done A-level mathematics but who were going to teach mathematics. Bernard Murphy got them doing A-level problems, taking time to engage with the mathematics—anything that allows teachers to spend time doing elementary mathematics and get inside their subject in a new way. A PGCE is so rushed, it is difficult to do this. Somehow that has to be fitted in as part of what I call the first three years novitiate of teaching—a kind of craft learning process. Then, when you are on top of that, you can start thinking more deeply about educational issues and reflective practice. But you have got to have something to get a hold of first, and that is missing. I think one could build it in. You could have internships of doing some elementary mathematics between second and third year undergraduate for people who might want to teach between third year and PGCE, but they have got to engage with elementary mathematics. We have to recognise that PGCE-type courses are far too rushed. There are all sorts of other practical pressures. They do not engage with the elementary mathematics in an easy way in order to think how to teach it later.

**Q77 Mr Stuart:** So what is the national centre doing to ensure that teachers get this deep understanding of the subject and do not just get another fancy-sounding title that actually has not equipped them with the basic skills?

**Jane Imrie:** I think that it is about working at a number of levels. Given that the national centre is itself relatively small, we don't work directly with teachers as such, but we try to work with and influence the people who do work with teachers; so, local authorities in particular. Note all the concerns we have—concerns that our research suggests are absolutely right—about the reduction in maths advisers, which itself has a knock-on effect for teachers engaging in mathematics, because in many authorities the focus tends to be on the failing schools and not on all the other schools.

**Q78 Mr Stuart:** In order to make it sound as if it's the same question and keep the Chairman off my back, National Strategies are going, so is there an enhanced role for the national centre to fulfil that

role? What are the issues around the National Strategies coming to an end and what can you do to fill the hole, if there is one?

**Jane Imrie:** There is a role for supporting subject leadership across the piece in mathematics at both the national and regional level, and to some extent supporting those who are working at local level; that is, in local authorities, HEIs and other clusters of schools. The co-ordination also has a quality role. For example, we have a standard for continuing professional development. When schools are responsible for organising their own CPD, how do they know what to choose? There will be a whole range of stuff out there. As I said earlier, providing advice to those non-specialists who are key in the new framework, particularly school improvement partners but also head teachers, is something that we do currently but I think that it would need strengthening as we move forward. I think that the concern for many teachers is that they are suddenly going to go from feeling highly supported to not feeling supported at all. So we also have a role in the transition from one regime to another. Going back to your question, we don't actually work directly with initial teacher education in many ways, but our tools are being used in initial teacher education a great deal. We have some fairly innovative tools for self-assessment, to encourage reflection and so on. Also, at a regional level we are promoting collaboration—I think that "collaboration" is a key word for the centre, because we cannot do it on our own—between local authorities and HEIs. There is a lot of evidence to suggest that in areas where the local authority is very active, teachers are taking up M-level courses more than in areas where the local authorities are not very active. Hence the need for mathematics advice at that sort of level. A lot of our work is with heads of departments and those influential teachers of mathematics, particularly advanced skills teachers.

**Chairman:** I don't want to be an unjust Chair, but I have to balance two sessions and ensure that everyone gets a fair hearing.

**Q79 Paul Holmes:** I was going to ask about the developments and new initiatives in maths teaching in primary and secondary schools, but you have answered that question really—it's all rubbish. Primary maths teaching is rubbish and getting worse; secondary maths teaching is rubbish and getting worse; training of maths teachers is rubbish and getting worse; the new curriculum will make the situation even worse; and the fact that more people are passing maths exams is a sign of failure. Is that a fair assessment of what you have been telling us for the last hour or so?

**Professor Brown:** There are a lot of bad things and there are a lot of things that have got worse, frankly, but there are some good signs, and I think we ought to talk about those a bit. The Williams courses, which are for primary leaders, have started only recently, but they are very exciting. People are very excited about them—the people teaching the courses and the people on them are very keen. So something is happening at last there, which is good. There are

the maths enhancement courses, which are the courses that people who do not have enough maths take before PGCE. They are probably not as good as the two-year PGCEs, but they are better than nothing. There are quite a lot of good things going on with those courses. The other thing that I think is working very well is the maths development programme for teachers, which is for non-specialist people in schools who are already teaching maths. So they are already doing maths teaching and actually they haven't got very much background in maths. Those courses are one day a week for a year, and they seem to be going very well and are spreading. So, where resources are put in—in fact, there was a big problem about that, because suddenly the Department for Children, Schools and Families removed the money for cover, so suddenly the courses didn't recruit. It was only when the money was put back that the courses recruited well, and they are now going well. So it is important to have the resources there to provide the cover to get people out to do these things. These courses all satisfy the requirements to have long-term courses taught by experts and focused on maths education and the knowledge you need for maths teaching. They are going well, but this is fairly recent stuff. I differ from Tony in that I think the new national curriculum is potentially okay, but it does need people to mediate, because it doesn't mean very much to a teacher looking at it—it's all generalist words. It allows people to provide good materials for teaching and good training for teaching, and the potential is there, but Tony is right in a way that it will not improve any teacher at classroom level as it stands.

**Chairman:** Unfortunately, Tony, *Hansard* readers can't see you shaking your head. You seem to be a bit of a Jeremiah in this.

**Dr Gardiner:** Yes, I'm afraid I am. Paul's directness is perhaps refreshing, but we have a traditional weakness, which has got worse since the '80s. In all policy making, one would like two things to happen. One is that you look at what's wrong and what emergency plumbing you have to do, and you think carefully about it. You may or may not have time to pilot, but off you go. But the second thing is that at the same time, you've got to think, "Is this a situation that we want our grandchildren to be in? Could we eliminate the cause in 10 years' time?" The question about emergency things for teacher training may be fixed in 10 or 15 years' time if you could, say, strengthen Key Stage 3 now. So you should be doing two things: you should be looking for the emergency plumbing and doing it as well as you can; but you should also be trying to reduce the amount of emergency plumbing that's needed in the long term, and we don't do that. What seems to happen, although I am not privy to the internal discussions, is that somebody looks and says, "Oh, we need a master's profession." It sounds terribly sweet, so they get the TDA to get the job done, and it devises something, but nobody thinks how to balance the short-term emergency plumbing with the long-term improvements. As regards the long-term improvements, in the far east, you find they have a

cycle of considering the curriculum carefully and they try to improve it. The 1999 national curriculum for mathematics was a decent working document. It got sidelined by the strategies, which were not statutory, but which always took precedence—it was very English. Then, when we came to 2007, all the content of the 1999 national curriculum was quietly ditched. This is a crazy way of proceeding; it's a knee-jerk response. We need to go back to thinking that education is a long game, and it's a very conservative outfit, so you want to plan slowly and improve. We've got to learn from some other countries how to do that better.

**Jane Imrie:** To some extent, I would agree with that. There is a need for an overview and for monitoring, rather than for lots of separate initiatives, so that there is some coherence across mathematics initiatives. Margaret listed some good things that have happened, and I would add to that list the Further Maths Network, now the Further Mathematics Support Programme, which has had a significant impact on getting young people to do A-level mathematics. There is also the former post-16 Success for All strategy for mathematics, which has infiltrated schools and been very successful. However, there is an issue about joining these things up and sustaining them. Many of the initiatives that are successful and valued by teachers are bottom up, but they are also short term ones, and the funding ceases. If you talk to teachers when a new initiative comes in, their mindset is often, "Well, it won't last for long, so if I don't get into it, there isn't a problem." The problem is sustaining these things and ensuring that the initiative achieves what we want. We have some outstanding advanced skills teachers in mathematics, and the NCETM employs some for their one-day-a-week AST work; they do fantastic work with other teachers. I talked to a very good AST<sup>1</sup> a couple of weeks ago, and for her one day a week she goes into a school to do revision classes for five hours with a class that is not likely to get a C. It is good that the class is getting a good teacher, but that is not what this role is about; it is about developing other teachers, so there is a question about how we embed the initiatives, get an overview and make sure that the good things are sustained.

**Q80 Paul Holmes:** From the point of view of how you analyse maths teaching in school and the output, Tony said that what matters is how good their maths is when they leave school at 18 or 19, but the vast majority of pupils will not be studying maths beyond 16. They will not be leaving school at 18 or 19 to go on to do maths, physics, engineering or whatever at that level. The last maths I ever studied was when I did O-level in 1975. When I was still teaching, 10 years ago nearly, I used to ask the maths department about all this. Those people said that maths teaching is much better now because it is aimed at the whole school population rather than

<sup>1</sup> *Note by Witness:* The AST I spoke to was not one of the NCETM team.

just at turning out people who are fit to go university to do STEM subjects, for example. So is it a different perception that we are talking about?

**Jane Imrie:** There is so much evidence that mathematics is life-enhancing, if you like, for want of a better term, at all levels. There is evidence to suggest that men and women over 30 who lack basic mathematical skills miss out on many chances, particularly women. They tend to be in unskilled jobs. They tend not to engage in political activity such as voting.

**Q81 Paul Holmes:** Sorry, but what do you mean by basic mathematical skills? The only maths that I have ever used since I was 16 and sat O-level has been addition, multiplication, subtraction, fractions and percentages. All the other maths that mathematicians love to talk about, the beautiful purity of maths and how important it is in physics just passes me and the vast majority of population by completely. What is basic maths?

**Jane Imrie:** I would argue that you engage in mathematical thinking quite a lot in your strategic discussions. There is a misconception that maths is all about fluency in doing sums, which is an important part of mathematics, but the thinking, reasoning and problem-solving skills that are engendered doing mathematics are very important. I was going to go on to say that at the other end of the scale there is evidence to suggest that people with A-level maths qualifications and above are among the higher earners and have the higher-status jobs, although not necessarily in mathematics. So mathematics is bringing in skills at all levels. There is a strong argument for mathematics to be continued through to 18, provided that there are appropriate pathways. If we just, as we tend to do now, take people through GCSE resit after resit, it is of no value.

**Q82 Chairman:** But have you not yourselves let the profession down in mathematics? Here you are, blaming the Government and blaming politicians. You are blaming almost everyone, whereas you are a professional body as mathematicians and there are people in the STEM subjects—they know that you nourish and nurture their subjects as well. They are going to join us in a moment. We check on what Ministers do. Ministers don't know about this stuff. They ask you as professional bodies. It is not a conspiracy to do down maths in our country. People have tried very hard to get this right, but do you have too weak a voice? You haven't really been successful in telling politicians and Ministers what you need and what you want.

**Dr Gardiner:** That is certainly true, but I don't think you can blame us.

**Chairman:** I'm not picking on you three.

**Dr Gardiner:** If you are not an expert in something, you should bloody well ask. And they don't. They sit in committees and talk to themselves. The TDA, for example, doesn't have anybody who knows anything about mathematics and the DCSF doesn't have anybody who knows anything about mathematics, yet they sit in committees and decide

things that affect mathematics and they don't tell anybody until they are policy. Then the poor bloody infantrymen have to try to fight the fire and make some sense out of it.

**Q83 Chairman:** But Tony, what if you were a doctor? I don't know a better pressure group than the medical profession, and it makes damn sure that nothing happens in the Department of Health that it doesn't approve of. Why aren't you as active, lobbying and pressing?

**Dr Gardiner:** If quadratic equations were poisonous and killed people, we might have some clout. They think they can sideline it. I disagree strongly with Paul. Maybe you are above it, but if ever you have ordered patterned carpet, wallpaper or cement for a drive, you end up using a remarkable amount of mathematics. The question is not whether I can persuade myself that I don't need it. I think you have to look at other countries and the way the world is going and decide, "Can we get by with this view that you don't need it?" STEM is irrelevant in some sense, as I think Jane said, because most of the applications of mathematics are not STEM, but management, or, computer science and so on. The world is now run by mathematics. The question is whether we are going to trot along behind other people or be up at the front.

**Q84 Paul Holmes:** But every subject discipline could sit there and say, "My subject is so important that it must be taught compulsorily up to the end of A-level."

**Dr Gardiner:** That's not what I said. I said the world runs on mathematics.

**Q85 Paul Holmes:** Jane said everyone should be doing some degree of A-level maths up to age 19. I have said the same about history. Modern language teachers would say the same about their subjects. You just can't do that, can you? Because there is not enough time and—

**Dr Gardiner:** I didn't do it and I won't do it. The world runs on mathematics, not on history.

**Paul Holmes:** But I use a computer constantly throughout the day, although I have no idea how it works. I turn on the car engine, I have no idea how it works.

**Chairman:** This could go on for a very long time, Paul. A very quick word from Margaret, then Jane, and we must end the session. I am sorry.

**Professor Brown:** We have a very effective—Tony would disagree—lobby group called ACME, the Advisory Committee on Mathematics Education. I was lucky enough to serve on it for a number of years. It was formed to get a single voice for maths education, which could talk to Ministers. My experience was that we spent hours and hours arguing with the quangocracy—all those people from quangos who did not understand what it was all about and who are making decisions. This is an endless problem about getting coherent policy in there. It might have been better if we had more time

with the DCSF, but I don't know, maybe it wouldn't have been. It was a real drain. It is very difficult to get anything into policy.

**Q86 Chairman:** But you had a Science Minister, Jane—David Sainsbury loved this stuff and was an open door to anyone like you, but you didn't step through it, did you?

**Jane Imrie:** We did. There is joint blame, if blame is the word, in that there is a lot of agreement about the principles behind effective teaching and what needs to be done. There perhaps isn't agreement in the community about the solution, but, as Margaret says, the community has got together and got behind ACME. There have been some frustrations working through that route. It is not that we are just sitting here and blaming Ministers; it is that Ministers can ease the way to make the solutions happen and, therefore, it is important that you understand the issues behind it. I would like to correct one point: I

was not saying that everyone should work towards A-level. I was saying that everyone should study maths to 18. It would be as appropriate, because if you are working, for example, in the humanities it might be that you are doing some statistics, or it might be that you haven't achieved sufficient level at 16, in which case start afresh and do more maths post-16.

**Chairman:** Jane, Tony, Margaret, this has been a really good session. You can tell from the liveliness of it that we would have liked to go on, but we cannot, and we had a bit of a late start. Obviously, reading between the lines, it is all the engineers' fault, and we are going to have the engineers here now. Thank you very much. Will you keep in touch with us? We would like this dialogue, and if you think of things you should have said to the Committee or which we should have asked you, we can continue the dialogue. Thank you very much. This has been a very good, lively session.

#### Memorandum submitted by Jane Imrie, Deputy Director, National Centre for Excellence in the Teaching of Mathematics

Thank you again for the opportunity to give evidence to the Select Committee last week. I mentioned that a number of contributions from the engineering group had prompted more thoughts and suggestions for further information. I hope the following will be useful.

#### LSIS STEM PROGRAMME

In response to a question from Karen Buck MP, about which STEM initiatives add value to Professor Matthew Harrison stated "I think that one of the ones that has made a real difference is the LSIS 16-plus programme, because engineering and technology are huge in further education and, as we all know, there have been well-publicised problems in the FE sector. It needs all the support it can get, so that is very straightforward."

The Committee might not be aware that this is the only STEM initiative in further education, and thus the only programme offering subject-specific support to teachers of science, mathematics, engineering and technology in the sector. The programme is led by a consortium of the National Centre for Excellence in the Teaching of Mathematics (NCETM), the National Science Learning Centre and the Royal Academy of Engineering and managed by Tribal Education. External evaluation states that its activity is well received, and feedback from teachers and senior managers indicates considerable impact. It has also been remarkably successful in engaging key partners and stakeholders, and a major aim is to encourage these groups to enable access to their activities for teachers in FE.

However, funding for the programme has been reduced year on year (£3 million in total this year for all STEM areas in the whole of the learning and skills sector), the current programme finishes on 31 March 2010, along with many LSIS programmes, and there is likely to be a huge loss of momentum while a new programme, with further reduced funding, is commissioned. Whilst it is inevitable that funding for all programmes is reducing in the current financial situation, an area of such major importance as STEM in FE, where there is huge potential for developing both a technical and an academic workforce, should at least be given more consistent input, if not greater priority. I would be happy to supply further information about this programme.

#### ENGAGING WITH MATHEMATICS

Professor Kutnick stated that "One of the things that consistently comes up about mathematics is that it is the most individually taught subject in the curriculum—teachers are focusing on individual children. If you compare that to what the Engineering Professors' Council found when it started looking at what you need as a background for engineering, you will find that yes, you need maths and science, but you also need the ability to work as a team, the ability to problem solve, the ability of self-efficacy to drive yourself forward with others, and you need entrepreneurship skills. Those are social skills and they are moving away from the individual . . . We need to get maths strategies that will be engaging for all children, rather than just the elite children. At the same time, we need to look at what I call the social pedagogic context, wherein how you learn and with whom you learn are vitally important. If it is just a teacher to an individual child, you are cutting off sharing of knowledge and the ability to develop social skills."

This statement might be seen as a criticism of the way mathematics is taught, but actually supports the thesis that we on the mathematics panel were promoting. Mathematics is a social and debatable subject. It is best learned when learners can struggle with the ideas, discuss them with their peers and their teacher, rather than note examples from the board and spend hours in solitude pouring over exercises. This is clear from a great deal of research. It has also been noted by Ofsted, and in the Williams Primary review, that such engagement with the subject is missing from too many classrooms, though, as Professor Kutnick says, it is crucial for developing the wider skills which are essential for STEM and other professions.

However, there have been a number of successful initiatives in recent years which aim to address this issue, notably in the post-16 sector, where the development of “Improving learning in mathematics” through the former DfES Standards Unit has impacted much wider than the sector itself. The work is based firmly in research, was trialled and piloted with over 100 teachers and 2000 learners and is focused on developing teachers of mathematics, regardless of phase or setting. It is also now used right across initial teacher education in all phases. This development has been acknowledged by the mathematics community as “one of the most significant developments in mathematics education in recent years”, and was made available to all schools. There have also been materials developed in the FE sector which contextualise these methodologies in areas such as engineering.

A related initiative, also in FE came from the DfES funded project “Maths4Life”, was based on “Improving Learning in Mathematics” and called “Thinking Through Mathematics”. This has only been distributed in the FE sector, though many primary and secondary teachers have expressed interest in receiving it and the NCETM has now made it available online. Again, the focus is on supporting teachers to develop their practice.

However, whilst there are such developments and resources, for many teachers adopting such approaches means rethinking their beliefs and practices, and this needs time to experiment, to try out different approaches and reflect on and share the outcomes. It also needs senior management support. In the best schools and colleges, there is an ethos which encourages and supports teachers to develop different approaches, “take risks”, reflect on and evaluate their teaching.

#### INTERNATIONAL DIMENSION

The issues around developing a more engaging, inquiry-based approach to teaching mathematics are not just a British problem. I am on an international consultancy panel for a new EU-funded project “Promoting Inquiry in Mathematics and Science” (PRIMAS) which involves 12 European countries. All are concerned that their mathematics teaching is focused on content and test results, rather than on developing mathematical understanding and enabling learners to use their mathematics.

The PRIMAS programme is clear that the primary issue is not about a lack of teaching resources, but lies in the necessity for professional development which is sustained and allows opportunities to try out ideas, reflect and revise, working collaboratively. Another major strand of the PRIMAS project is in helping learners, their parents, senior managers and policy makers understand why such approaches are beneficial, recognising that these groups may have a very different view of mathematics, based on their personal experience.

#### GREATER COHERENCE ACROSS SCHOOLS AND FE

A further important point in noting the above is that materials such as “Improving learning in Mathematics” are appropriate for all phases, just as some resources in schools are relevant across all phases. Equally, there is evidence that teachers working on mathematics and mathematical pedagogy in cross-phase networks have considerable impact on improving transition and progression. However, often teachers in different phases and sectors do not have access to developments or networks from each other’s phase, even though this is not only desirable from the perspective of raising standards, but also to avoid unnecessary duplication.

Related is the important point raised in the Select Committee’s report on the *Training of Teachers* that teachers in schools and FE should be working to a common set of standards. The Committee might also note that teachers of adult numeracy in the FE sector are required to have achieved a Level 3 entry qualification. The specification for this is set by LLUK and poses greater demands than GCSE Grade C, but focuses on developing process skills rather than adding too much content.

#### LEARNING OUTSIDE THE CLASSROOM

As the Committee is currently taking evidence on Learning outside the classroom they might wish to know about the mathematics strand of the recent DCSF project in this area. The NCETM led this strand and aimed to demonstrate the richness of mathematics learning that is possible outside the classroom situation. Further details are available here <https://www.ncetm.org.uk/resources/9268>

### Memorandum submitted by Engineering UK

Thank you for the opportunity to submit written evidence to the Committee and come before you on 10 February, as part of your inquiry into the teaching of STEM subjects. This document provides an outline of our work and our responses to questions the inquiry remit raises.

#### 1. EXECUTIVE SUMMARY

EngineeringUK believes there are a number of important issues an inquiry into the teaching of Science, Technology, Engineering and Mathematics (STEM) should examine:

- (i) Engineering is the only STEM subject not routinely taught as part of the curriculum. So it is crucial that engineering is linked to other STEM subjects by teachers and advisers, and that the wider engineering community is able to forge links back into the classroom and to schoolchildren.
- (ii) Career paths in and into engineering are misunderstood by both students and their career advisers—40% of advisers wrongly believe that A-levels and degrees are the only route to an engineering career.<sup>1</sup> There needs to be much clearer signposting of the routes into engineering.
- (iii) STEM subjects can be overwhelmed by a plethora of initiatives. We support co-ordinated programmes that bring together multiple initiatives and organisations. Our programmes are targeted where need is greatest and evaluated so we can assess their impact.
- (iv) The teaching of STEM subjects requires motivated and inspirational teachers. We believe the importance of continuing professional development (CPD) in both subject area and teaching style cannot be overestimated.

#### 2. BACKGROUND

##### 2.1 *Engineering UK*

- (i) EngineeringUK is an independent, not-for-profit organisation which promotes the vital contribution that engineers, and engineering and technology, make to our society. We also aim to inspire people at all levels to pursue careers in engineering and technology.
- (ii) EngineeringUK leads on “The Big Bang”; the UK’s Young Scientists and Engineers Fair. This year’s Big Bang will take place at Manchester Central Convention Complex, 11–13 March, and will feature the National Science and Engineering Competition.
- (iii) The inaugural Big Bang in 2009 set a new benchmark for STEM engagement and we expect it to be three times bigger this year with over 15,000 children attending on school days—the equivalent of more than 500 classes. The Big Bang will travel to different locations around the UK to ensure a truly national reach and our ultimate vision is that every child in the UK knows someone involved with the Fair.

##### 2.2 *Engineering background*

- (i) Everybody needs water, power and a place to live. And engineers are essential for all of these things. So there is a significant national interest in developing and maintaining a world class talent pool of engineers at all levels.
- (ii) There exists in the UK a comprehensive set of engineering institutions and academies, as a result of the UK’s historic legacy in engineering and its importance to a wide range of industries. The community has commented elsewhere on the potential for such structures to best serve skills development in the UK.<sup>2</sup>
- (iii) Indications are that once the UK starts its economic recovery there will be considerable demand at all levels with a forecast requirement for 587,000 new workers in manufacturing in 2017.<sup>3</sup> This is amidst the backdrop of a declining demographic base from which to recruit young people over the next decade.
- (iv) There are a wide range of pathways into the engineering profession including apprenticeships, diplomas and degrees, all of which require considerable investment in terms of time and resource from learners, current or future employers and education providers. In addition to this there are opportunity costs associated with earnings foregone by learners and the potential to outsource work to countries with ready-made workforces for employers.

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<sup>1</sup> *An Informed Choice: A Roadmap for Increasing Careers Information, Advice and Guidance Throughout The UK*, EngineeringUK 2009.

<sup>2</sup> *Engineering Skills*, The Professional Engineering Community, 2009.

<sup>3</sup> *Ibid* p 22.

### 3. THE STEM CURRICULUM, INCLUDING THE EFFICACY OF RECENT PROPOSALS TO IMPROVE MATHS TEACHING, AND THE STATE OF ENGINEERING EDUCATION IN SCHOOLS

- (i) Since it is not taught as a specific part of the curriculum, engineering relies on the other STEM subjects to provide a solid foundation for careers in the sector. Extra-curricular enhancement and enrichment activities are vital in helping pupils make the link between subjects learnt in the classroom and their real-world application. Pioneering extra-curricular programmes such as The Big Bang and Tomorrow's Engineers are discussed in sections 5.1 and 5.2.
- (ii) There is considerable variation in both the forms of teaching and the popularity of STEM at different levels across the UK education systems. Research by EngineeringUK has shown that amongst 7–11 year olds, Art and Design is the favourite subject, with Design and Technology in third place—both are STEM subjects. Children say they prefer these subjects because they enjoy the design and building element and the opportunity to be creative.<sup>4</sup>
- (iii) In contrast, Physics is the least popular subject for this age group but it is a pre-requisite for most engineering courses in higher education.
- (iv) Greater emphasis needs to be placed on linking the perceived enjoyment and creativity of Design and Technology to the underlying necessity for a comprehensive understanding gained through Physics.<sup>5</sup>

### 4. VOCATIONAL PROVISION IN THE STEM SUBJECTS, PARTICULARLY ENGINEERING

- (i) Many advisers and trusted intermediaries are not familiar with the routes and qualifications needed to pursue a career in engineering. Research by EngineeringUK showed that 40% of advisers wrongly believed A-levels and a degree is the only route to an engineering career.<sup>6</sup>
- (ii) It is vital that careers information and advice about careers in STEM is visible and accessible. There need to be coherent messages about STEM careers, supported by a range of institutions and organisations drawn from the whole sector.
- (iii) One notable area where progress has been made is in BTECs, where the first diploma makes a significant contribution towards providing young people with engineering and construction skills. The latest Edexcel figures show growth of 89% and 340% from 2006–07 in entrants to engineering and construction skills respectively. In 2009–10 the entrant numbers to BTEC Firsts were 5,879 to engineering and 4,986 to construction skills.

#### 4.1 *The Engineering Diploma*

- (i) We welcome the Engineering Diploma as a pathway into the engineering profession. The Engineering Diploma provides a good mix of academic and vocational learning which has all the potential to appeal to a significant demographic of students and to employers who call for these mixed skills.
- (ii) Initial signs are positive for the Diploma: so far approximately 7,000 learners are enrolled at all three levels—this is equivalent to about half of all undergraduate students studying engineering. In its first year (from September 2008), 1,710 learners enrolled in the diploma. Approximately 5,000 learners are estimated to have started in 2009.<sup>7</sup> So far over 1,000 employers have signed up to help with work-related learning. These vary from major contractors and the large utilities companies to local businesses.<sup>8</sup>

### 5. INITIATIVES TO PROMOTE THE TAKE UP OF STEM SUBJECTS AT SCHOOL, COLLEGE AND UNIVERSITY

- (i) The challenge facing the STEM community is co-ordinating the plethora of initiatives facing young people and their advisers and other trusted intermediaries. This is a challenge being addressed by our key programmes—The Big Bang and Tomorrow's Engineers. These bring together a wide range of initiatives and partners. They are also targeted and evaluated to make the most difference.
- (ii) Despite numerous initiatives encouraging young people to study STEM subjects and pursue STEM careers, young people remain the demographic group with the least positive perceptions of these subjects. Only 18% of 11–16 year olds perceive engineering as a desirable career. There are however, some signs of progress, particularly in 16–24 year olds, whose perceptions of engineering have increased by 5% in the past year.<sup>9</sup>

<sup>4</sup> *Rebuilding the UK Economy: Changing Perceptions of Engineering*, EngineeringUK 2009.

<sup>5</sup> *Ibid.*

<sup>6</sup> *An Informed Choice: A Roadmap for Increasing Careers Information, Advice and Guidance Throughout The UK*, EngineeringUK 2009.

<sup>7</sup> *Ibid.*, p 70.

<sup>8</sup> *Ibid.*, p 70.

<sup>9</sup> *Rebuilding the UK Economy*.

- (iii) Despite the multiplicity of STEM initiatives in place, there is a risk of these being inappropriately targeted or insufficiently evaluated. Currently, only 35% of the public and only 30% of 11–16s had seen, heard of, or visited something in the past year that presented engineering in a positive way and inspired them.<sup>10</sup>

### 5.1 *The Big Bang*

- (i) The Big Bang: UK Young Scientists & Engineers Fair is an educational experience for young people aged 9–19, showcasing innovation and creativity. Science and engineering achievement is rewarded at the Big Bang through the high profile National Science & Engineering Competition Awards.
- (ii) The inaugural Big Bang in 2009 set a new benchmark for STEM engagement. This year it will be three times bigger with over 15,000 schoolchildren attending—the equivalent of more than 500 school classes. The Big Bang will travel to different locations around the UK to ensure a truly national reach and our ultimate vision is that every child in the UK knows someone involved with the Fair.
- (iii) The Big Bang leads the sector in terms of large-scale collaboration between STEM partners. Led by EngineeringUK in partnership with the British Science Association, the Royal Academy of Engineering, the Institute of Physics, Science Council and Young Engineers, it brings together over 70 organisations and STEM providers. This year the Fair also enjoys support from government, Lloyd's Register Educational Trust, Astra Zeneca, BAE Systems, Siemens and Shell, The Wellcome Trust and the North West Development Agency, among others.
- (iv) We are developing our series of Regional Fairs held in June and July every year, providing similar regional platforms for STEM engagement to promote and engage with young people and teachers directly. As part of this activity, we seek to increase one-on-one engagement dramatically from 20,000 people at the national Fair, to 30,000 at the regional level. More than just creating yet another STEM enrichment event, we aim to use these events as a way for the wider regional STEM communities to tap into The Big Bang brand, to promote and engage with local young people, teachers, business and industry.
- (v) A new element to this year's event is a full day programme of CPD aimed at teachers from Primary and Secondary levels, including a series of Masterclasses, CPD courses and workshops on a wide variety of subjects with the National Science Learning Centres, National Centre for Excellence in Teaching Mathematics and Association of Science Education.
- (vi) Independent evaluation of the Big Bang Fair is being carried out by the Centre for Science Education at Sheffield Hallam University.

### 5.2 *Tomorrow's Engineers*

- (i) EngineeringUK and the Royal Academy of Engineering are making a determined effort to encourage more students to think about career opportunities in the various fields of engineering through the Tomorrow's Engineers Programme, targeting those schools and students where we can make the biggest impact.
- (ii) In line with the Westminster Government STEM Programme, the Tomorrow's Engineers Programme aims to assist partner organisations focus their individual and joint efforts so that students, their teachers and parents have a better appreciation of engineering and the many paths into the profession that are available.
- (iii) This programme will provide funding and other support to key STEM activity providers, to promote engineering in schools. Careful targeting will be used to maximise impact and to identify those schools and students that are performing well in subjects that may lead towards a career in engineering. It will also target those schools and students classed as 'hard to reach' where participation in enhancement and enrichment programmes have traditionally been low.
- (iv) Priorities for ongoing support will be made on the basis of evaluation evidence. The long term vision is to make a continuous programme of evaluated engineering enhancement and enrichment activities available to hard-to-reach students, their teachers and parents across the UK.

February 2010

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<sup>10</sup> Ibid.

*Witnesses:* **Professor Matthew Harrison**, Director, Education Programmes, Royal Academy of Engineering, **Paul Jackson**, Chief Executive, Engineering UK, **Chris Kirby**, Head of Education, Institution of Mechanical Engineers, and **Professor Peter Kutnick**, Professor of Psychology and Education, King's College London, gave evidence.

**Q87 Chairman:** I welcome Matthew Harrison, Paul Jackson, Chris Kirby and Professor Peter Kutnick to our proceedings. I think you heard, but we try to keep the informality in our proceedings, so do you mind if we don't call you professors all the time? Is that all right—just strip down to first names? Thank you very much. I am very pleased that you were all sitting there for that first session. I think you will agree that it was a lively one, and I hope we can build on that, but I am going to ask you not to do a first piece, but very quickly to put this in some kind of context—I really mean briefly, because I want the questioning to be the main thing and we have barely an hour, if that. Start with Matthew.

**Professor Harrison:** Engineering is relatively new in schools—perhaps for the last five years as a curriculum subject—although engineering activities have been taking place in and around schools for at least a generation. Our view at the Royal Academy of Engineering is that the Key Stage 4 curricula—the mainstream curricula in engineering—are broadly correct and about right. There are issues, though, particularly around the number of specialist teachers available to teach them, initial teacher education and professional development—although that is for teachers. The curricula are right. There are a good number of young people studying these mainstream engineering curricula—we are talking about the GCSE, the BTEC and the 14–19 diploma. There are around 40,000 young people at Key Stage 4 studying them today. I would maintain that those curricula have made a good, strong and healthy start, but they need some time to bed in, and we need to support the teachers who are teaching the curricula now, so that they get a decent chance and a fair crack on the whip.

**Paul Jackson:** I take a slightly different perspective from Matthew, although we work very closely together, because my organisation promotes engineering and looks at working on the supply of engineers. From our perspective, the E in STEM is largely silent in schools. It starts to come up rather later in school life, but it's not in the curriculum. We see that as being a very real issue, one that we try to work on with others to put enhancement and enrichment activities in. One of those is the Big Bang Fair, which I think the Committee is aware of, which has brought together lots of organisations, including from the science, maths, technology and engineering communities to enthuse young people, but we are trying to get away from “it's a single day out” to “it's a year-round activity” of encouraging young people and painting the rich picture of opportunity that is there later in life if they stay in touch with the subject through school. We think that that's incredibly important. The landscape needs to change on that if we are to encourage and enthuse young people in the future.

**Chris Kirby:** There are some areas of clear agreement with colleagues on my right and, surely, Peter on my left. The visibility, or otherwise, of engineering in the school curriculum is a key issue. In fact, visibility of engineering in schools in any form is probably an

issue as well. Secondly, with the enthusiasm, or otherwise, of students to engage in mathematics, science, design and technology and engineering—whatever they are presented with—there is an ongoing issue there, not just in the UK, but internationally, as I am sure most people around the table know. We are concerned about teacher numbers, particularly in physics, but also in science more generally and mathematics, and the skills that they require to teach those subjects for the world that is coming rather than for the world that has passed. Looking at that in particular, we're interested in the issue of how the different sciences link to each other, or whether they are taught discretely at schools. I think there is some evidence that there aren't enough horizontal linkages between the subjects in schools. Looking vertically, the transition between primary and secondary schools appears to be an issue, where motivation is lost through a variety of means. We feel that the key issue is about ongoing engagement and motivation over a period of time, be it through the curriculum or the wide range of good enhancement and enrichment activities that are made available. It is about a journey, to use the J word. We need to ensure that young people are on that.

**Q88 Chairman:** Peter, are you a subversive from University College?

**Professor Kutnick:** King's College.

**Chairman:** We have a lot King's College people here today. At the London School of Economics we sort of worried about you. We thought you were a strange mixture of scientists and theologians over there.

**Professor Kutnick:** There is someone else in the room we can blame for that, but I won't name names. I am a latecomer to engineering and engineering education. My role, and my access to it, when I was asked by engineering professors to look into the design of some sort of longitudinal study, because there are virtually no academic studies on engineering education. Those studies that do exist tend to be what I would call backwards-looking. They look at engineers who have gone into HE, they get these engineers to talk retrospectively about certain key elements in their history and then assume that all they need to do is re-create those elements and you can have more engineers. That is a total misconception of the potential of trying to get a much bigger pool of people going into engineering. I will start there—there are lots of things to go into. We need to remember in engineering that it is not just for HE. There is a lot of low-level and mid-level technical engineers that must be trained and there are a number of courses starting to come up. Let's not forget them. Let's not put them out. Hence, they need appropriate teaching and appropriate support at various levels, so it is not just for the elite. Many other problems lie therein. One of my key concerns about the aspects of engineering that we find in the school curriculum now is that they tend to be in

secondary schools, and later on in secondary schools. If you look at the career aspiration literature, what we find is that, usually by age 14, most children have quite a good idea of what career they want to aspire to. At that age—when the engineering diploma comes in, when the BTEC courses come in—children have already largely made decisions, so we need to bear that in mind. We also need to look at—because engineering is not so deeply embedded in the curriculum—where kids get their engineering experience. There is one area of the literature about parents and home background, but there is another area, which we are looking into in much greater depth, about the role of extracurricular activities. There is a plethora: many, many organisations provide very interesting experiences for kids in schools, but they tend to come in on a one-day basis or sometimes take the kids away for two or three days. And, many of those experiences are aimed just at sixth-formers; they've already decided they're going into engineering, so it is a matter of when they come in. There is a bit of a leakage problem. Within the extracurricular activities, we have done some analysis and we find that there is a certain weakness in conceptualising what one might call engineering pedagogy. There just doesn't seem to be an engineering pedagogy. There seems to be a lot of "let's plan and do", but if you go into a teaching pedagogy, there is a plan-do-reflect-upon mentality. We are wondering how that fits into this. I will stop there.

**Chairman:** We will drill down with Karen, then.

**Q89 Ms Buck:** I think you were all listening to the questioning of previous witnesses and the talk about the effectiveness of the sectors in both lobbying and being a pool of expertise to influence government. I just wondered if, in your view, value is added by the contribution of all the following: the Government's STEM cohesion programme; the DCSF-DBIS STEM Board; the LSIS STEM Support Programme; the Qualifications and Curriculum Authority; STEM Advisory Panel; Engineering for Education Policy Group; Science for Careers Expert Group; Science for Careers Expert Group; Post-16 STEM Programme Advisory Group; Further Mathematics Support Programme; Higher Education STEM Programme; Higher Education Academy Engineering Sub-Committee Steering Group; and the various STEM professional organisations? Is that the right way to present advice?

**Professor Harrison:** I have the rare distinction of sitting on every single one of those boards.

**Ms Buck:** And you are actually only 19.

**Professor Harrison:** And I am only seven.

**Chairman:** That is a much better conspiracy than the mathematicians.

**Professor Harrison:** There is a plethora of STEM initiatives, and in my view they are not really STEM initiatives in the main. They are very frequently science and maths initiatives, and the E and the T can be attenuated almost to extinction. The reason I sit on all those things is regularly to remind other participants that there is an E and a T and together

they are motors for the economy, and also because engineering as a profession is a route to social mobility. As Peter said, it can be a route for social mobility for a family who have nothing to do with higher education, but celebrate the fact that their son or daughter gets an apprenticeship with a well-established firm and goes on to make a useful and productive life for themselves. I am glad that there is attention on STEM. We are working hard to see E and T come up, but the funding that flows into the E and the T in all those things is minuscule and in some cases negative, so the Royal Academy of Engineering is in many cases a net funder of the STEM programmes. I think that one of the ones that has made a real difference is the LSIS 16-plus programme, because engineering and technology are huge in further education and, as we all know, there have been well-publicised problems in the FE sector. It needs all the support it can get, so that is very straightforward. The STEM cohesion programme is also worth singling out, because industry puts a lot of money into extra-curricular activities and teacher support, and it can be diffused by the fact that lots of people are nobly trying to make a multitude of contributions. If we can start to bring that together in a more cohesive way, it will be a better return on industry's investment, it will mean less distraction for the schools and colleges sector, and we can expect greater impact. I think they are a good thing, but we also need to see some consolidation in the number of these boards.

**Ms Buck:** Not another life wasted.

**Professor Harrison:** No.

**Paul Jackson:** Can I come in, partly to help Matthew free up some spare time in the future. I think that would be valuable. There is no shortage of volume in bodies, whether the body is directly supported by government or is outside government. Of course, in the devolved nations there is another set as well, although it is a rather more focused set in most cases. What we are very keen to see is the initiatives from Government and those from third sector bodies such as ours and from business coming together in a coherent way. If we can get them all pointing in the same direction and giving consistent messages to young people that encourage them to come into STEM, that will be incredibly valuable. But a smaller number of more focused bodies, with some activities as a result, which are effectively targeted and evaluated will be important. The manufacturing sector is five times the size of the financial services sector in the UK. It is important that this is looked after, but this doesn't look optimum.

**Q90 Chairman:** Let us just push you a bit on that. The maths people are basically letting you down, aren't they? They are not getting enough enthusiasm for maths, and you can't do engineering without some grounding in maths. What would you say to the people who just gave evidence about improving the quality of the raw material that you get? You want people with some maths content, don't you?

**Paul Jackson:** I will come in on motivation.

**Chairman:** Don't answer that. Graham, why don't you come in?

**Mr Stuart:** You always take my best questions. Will the witnesses pretend that it was asked with more passion and greater accuracy, and respond appropriately?

**Chairman:** We must be getting to the end of term.

**Professor Kutnick:** I apologise in advance for stepping on toes, but you are right in terms of maths as essential. One of my colleagues, Jonathan Osborne, who is now over at Stanford, would say that if you really want to have the route into engineering, what you need is good mathematicians. Therein lies the question: how do you get good mathematicians? One of your earlier debates asked: do we just need to train for the elite mathematicians, or do we want the mass of kids going into it? I have done a number of studies with Peter Blatchford at the Institute of Education on what we call mapping classrooms. You make a physical map of the classroom and then draw in what people are doing, how they are doing it and with whom they are doing it during lesson time. One of the things that consistently comes up about mathematics is that it is the most individually taught subject in the curriculum—teachers are focusing on individual children. If you compare that to what the Engineering Professors' Council found when it started looking at what you need as a background for engineering, you will find that yes, you need maths and science, but you also need the ability to work as a team, the ability to problem solve, the ability of self-efficacy to drive yourself forward with others, and you need entrepreneurship skills. Those are social skills and they are moving away from the individual. If I were to come back to the maths people, I would say, "Yes, maths. It's fundamental." We need to get maths strategies that will be engaging for all children, rather than just the elite children. At the same time, we need to look at what I call the social pedagogic context, wherein how you learn and with whom you learn are vitally important. If it is just a teacher to an individual child, you are cutting off sharing of knowledge and the ability to develop social skills.

**Chris Kirby:** I don't have a problem with what has been said, but I want to add a slightly different dimension to it. We are asking how maths and science can contribute to engineering learning. Actually, we might want to think about it the other way around: how can we use engineering and design and technology, for example, to inculcate greater enthusiasm and interest in science and maths, which will then feed back into more enthusiasm and interest in engineering? I think that for me it still comes back to the issue of motivating young people, and teachers are probably the key influence there. Perhaps we need to turn it around and ask how we can use what is on offer here to facilitate learning in maths and sciences.

**Q91 Chairman:** So you can teach maths without kids knowing that they're learning maths by using engineering.

**Chris Kirby:** I can give you precise examples of that, where children between, say, 11 and 14 are building single-seat racing cars powered by electricity and

using maths to calculate the life of the battery. They want to do it, and they ask how they can get more out of it, whether they can use the maths to look at the friction of the tyres on the road. Because they are engaged in it, they don't actually realise until afterwards that they are learning. I am getting a little bit carried away.

**Chairman:** Tony from the previous panel is both smiling and shaking his head.

**Chris Kirby:** That doesn't surprise me.

**Mr Stuart:** I have noticed that Tony shakes his head both when he agrees with the awfulness of the thing being described by someone and when he disagrees with it, so it is actually impossible to read anything into the shaking of his head. He just does it a lot.

**Chris Kirby:** I look forward to a conversation in the corridor outside.

**Q92 Mr Stuart:** This is an interesting point, because of course there are structure issues here in terms of school time and curriculum. I know that Matthew is a great proponent of driving engineering into schools. He sits on some of these bodies, and, unlike the mathematicians, he gets his agenda through, and engineering is being pushed down into schools. The question is, is it a suitable school subject? Or do we need to just sit there, however dull it is, however hard it is to engage, and learn, as they do in other places? We can enthuse people about maths, perhaps by using some engineering concepts, but we teach them maths, and, until we have taught them basic maths, we recognise that they are not going to be great engineers. To bring engineering down and displace effective maths with substandard teachers of engineering, as can happen all too often, could be an entirely false agenda, however brilliantly pursued by Matthew. Does anyone have any sympathy with that point of view?

**Professor Harrison:** At the Royal Academy of Engineering, we talked about this a lot. It took two whole council meetings to debate whether we would support a 14–19 diploma in engineering when it was first put forward. We decided, yes, we would, for these reasons: one, engineering is a motor to the economy, so there is a strong economic driver; two, it is an agent for social mobility; and, three, it is very enjoyable, so students can have it as the highlight of the week. But there is a real danger that young people could specialise too early, and so with this extra opportunity comes the very definite need for improved information, advice and guidance. In a school that is expert in the way that it delivers the engineering curriculum, that centres it around excellent advice to young people, where you have cross-curricular working so that the engineering department can support what design and technology, science and maths are trying to do, in those perfect conditions it's a great choice for a number of students who would find it compelling and exciting, and it would make sense of their week. If engineering is shoehorned into the wrong school, unsupported, where the poor old D and T teacher tries to make a good go of it and there are no

mechanisms to make sure that the right students elect the option, it is a bad thing. My final point is that, at Key Stage 4, engineering is just an option alongside the core curriculum of maths, ICT, science and English. As an option, it might displace some elements of modern foreign languages, or humanities, but for some students that is a price that they would be willing to pay.

**Professor Kutnick:** I will come straight out with a political statement and say that we are on fairly insecure grounds, because there really is not any solid research in this country about engineering education at schools, and we are trying to develop it. The Royal Academy is currently supporting a large-scale systematic literature review. Some of the things that are coming out are interesting. You may or may not know that the state of Massachusetts in the States has engineering and technology built in as a fundamental aspect of its curriculum through its elementary and secondary schools. I have just become aware of that and I am not aware of whether there have been any evaluation studies. Part of the question is, “Can it be,” and the answer is, “Yes it can be,” especially if it is tied, as Matthew said, to enthusiasm and interest. If you make a parallel to the maths education, the most effective maths education is at primary level. That is where children take meaningful issues, issues about the environment and about their lives and work from them. There is quite a divergence when you move into secondary schools, because there are more subject-specific topics, and even science and maths are broken down into particular units. They lose that integration that seems to be strongly tied to their enthusiasm.

**Q93 Chairman:** Peter, isn't it true that even in the UK, if you go into primary schools, you see children doing engineering? All that constructive play, building bridges, measuring and so on, is early engineering.

**Professor Kutnick:** It sounds like it, if you can get the children then to reflect back on what they have done.

**Chairman:** Perhaps you are being too conservative. Perhaps you guys should be teaching engineering at pre-school.

**Mr Stuart:** Early years foundation stages.

**Paul Jackson:** Winding back to Key Stage 2, I think that your observation, Chair, is absolutely correct. There are many aspects of design and technology, which is one of the highest rated subjects in terms of student popularity, that look much like engineering, including a bit of teamwork typically. We do not call it engineering, and we take an annual survey of young people and adults in which they tell us that 50% of them at that age think that engineering is boring and yet they rate design and technology as one of their most popular subjects. There is a connection, picking up on Matthew's earlier point about the careers context. I am talking about not detailed careers guidance but alerting them to the possibilities. We think that that is incredibly important and can really bring maths and the science curriculum alive. That takes a bit of effort.

**Q94 Chairman:** I got the impression that mathematicians don't like teaching maths by stealth. Did you get that impression? You listened to the evidence. Is dressing up maths as engineering, maths by stealth?

**Professor Harrison:** I always find it hard to find the boundary between engineering, science and maths. Searching for the boundary is probably a fruitless task. The point that I was hoping to make was about the state of technology at primary schools. In June 2008, in its review of design and technology in schools, Ofsted said that “at least two thirds of the primary schools and a third of the secondary schools visited have still not realised the potential of design and technology to help all learners become confident and capable members of a technologically advanced society.” That means that two thirds of primary schools are not doing it very well. The reason why I want to raise it is that the Secretary of State welcomed all of Jim Rose's recommendations for the new primary curriculum that comes in in September 2011. Then we will see a new area of scientific and technological understanding [in the curriculum], which will be built into a primary school system that has struggled to deal with design and technology. I have genuine concern that a sixth of the primary school curriculum is intrinsically weak, unless we can do something very quickly.

**Q95 Paul Holmes:** With the new teacher training for engineers, there are only four universities, all modern, post-1992 universities, that have introduced teacher training for engineering. Why are the self-styled top universities not interested in the subject, and what are you doing about it?

**Professor Harrison:** I can confirm they are interested because I keep having phone calls from top universities who are saying—

**Chairman:** Do we have to say top universities? Can we say research-led?

**Paul Holmes:** Self-styled sounds good.

**Professor Harrison:** Self-styled, research-led universities. The quick answer to that is that a call for interest was put out and a number of universities were quick to respond. They were post-'92s. Their provision of engineering fitted very neatly into existing activity around design and technology, and other allied subjects. I can see why those universities put themselves forward and got to the front of the pack. Perhaps a little belatedly—but it is welcome that this is happening—very selective research-intensive universities are expressing an interest. Their principal concern in an environment where we have seen deep cuts to the higher education budget is whether there is enough demand for it. One of the roles I feel that I and the Academy have is to point out how much of Key Stage 4 mainstream teaching is going on, particularly in engineering. So we have 40,000 kids studying it. In London alone, 216 schools are involved in the engineering diploma. It is an awful lot of provision and for one of the well recognised—internationally recognised—universities in London that is quite a good market for them to serve. So I fully expect to see a much wider range of IT providers in the next year or two.

**Q96 Paul Holmes:** One of the problems for the initial four providers is getting enough placement opportunities for the trainees. Why is industry so slow to provide these sorts of opportunities? On Monday, I asked the same question to a group of business people. They are always saying they need more people coming into industry and business, but they do not seem to be as forthcoming in providing apprenticeships and engaging with the education system as Germany, Sweden, Denmark or other countries.

**Professor Harrison:** If I might hazard the first answer to that. There are two things happening. In general, the UK Commission for Employment and Skills was quite bold in its *Ambition 2020: Skills, Jobs, Growth* report in saying that it felt there was a lack of ambition among employers for training. That would include training the next generation of engineers and technicians who are going to come first on work experience. There is the hint of a cultural problem there, but it is not universal. There are some very well recognised engineering employers who go out of their way to ensure that all the plants and the various regional offices provide good quality work experience. They are the usual suspects—the Rolls-Royces, the JCBs, the Thales, the BAE Systems and so forth. That is fantastic, but they only cover certain locations in the country. Where we need to see real movement is at those firms at the top of the pecking order of the supply chain. They need to start imposing at least a cultural expectation, if not a contractual obligation, on their suppliers for doing likewise. A good example of that is what Transport for London does in London. It imposes skills clauses on its contractors and their suppliers, so it says, “If you want to help us build Crossrail, you will offer this many apprenticeships, and this many student bursaries. You will open sites up to local schools and you will give work experience.” That is a fantastic use of the muscle of the public purse to lead to change.

**Chris Kirby:** Something that Matthew’s hinting at there as well is that, of course, for the vast majority of companies who are small and medium-sized enterprises there are some real issues about cost. Along with that, I suggest that in my experience there is also on the part of many people in industry—despite the enormous amount of good work that is done—an assumption that they understand the education system. If they are like me, they went through it years ago, and they don’t understand how it has changed and what they can contribute. So there are issues about just how employers and schools talk to each other, use common language and generate a common understanding, so that employers can see that they are investing, not just taking on a cost.

**Q97 Paul Holmes:** What can we do about that? My constituency used to have coal mining and engineering, but that has all gone. The big engineering firms that would have provided these placements—Donkin, Markham and the Coal Board—have gone. But there are still a hell of a lot of SMEs involved in engineering. If in the Chesterfield

area, which is typical of lots of parts of the country, we are going to get more children involved in engineering, the SMEs have got to be the people who provide the placements for trainers and apprentices. How do we do it?

**Chris Kirby:** Matthew has already alluded to some structural approaches in terms of mobilising supply chains and so on. We’ve found at the Institution of Mechanical Engineers—and other institutions have also found this—that probably the most powerful thing at our disposal is the motivation of individual engineers who see a need to do something to encourage the next generation of engineers and they will sign up as science and engineering ambassadors or to individual professional engineering institution ambassador schemes. They will go to schools and work with the support materials that we provide them with, or whatever.

**Q98 Chairman:** On Paul’s point, I still have a vibrant group of engineering companies in Huddersfield, but they’re much smaller and there are fewer of them than there ever were to providing the link that could do that. You are quite right that the SMEs must be the route if you’re going to get that connection. But some parts of the country have no engineering life left in them, have they?

**Paul Jackson:** Involving the SMEs is essential. The mismatch between the 200-odd schools and colleges involved in the diploma in London and the blend of the engineering sector in London, which has some major projects but is largely SMEs, has to be taken care of through frameworks so they can get involved. It’s not as straightforward to get the return on the investment for an SME, where for a major company like Rolls-Royce or BAE Systems that person will come into employment at the end of an apprenticeship and it’s a pretty straightforward return on that investment and really worthwhile. An SME may not have that space available. So the framework to link them to schools and colleges is important. That has got to be provided centrally to make it work.

**Q99 Paul Holmes:** In Denmark a few years ago, we saw a massive apprenticeship system still. Everything, from the shoe shop on the high street to the engineering firm, took apprentices because they all had to pay a training levy to the Government, which went through the FE colleges. Apart from the construction industry, we’ve moved completely away from that. So how do we incentivise SMEs to say, “This is worth our time?”

**Professor Kutnick:** Just a slightly different perspective with the SMEs and the apprenticeships. A lot of the industrial money that goes into engineering education tends to hit the target-age kids in schools. Let’s step back and broaden it a bit. We need a wider conception of entering engineering and what industry can do when they step in. Let’s just take some of the BEST programmes, such as You’re in Industry and Headstart. The problem is not that they’re not interested in more people going

into engineering—these are people who've already chosen to go into engineering—the programmes are just stopping a bit of leakage of other people who are very skilled who might be drawn up. So there's this tension between maintaining a certain flow, as opposed to expanding. Where do you expand? If you expand too late in age, kids have already made those career aspiration choices much earlier.

**Professor Harrison:** I just want to take up this issue of whether there are areas of the country without engineering. I'd say no, because every area of the country's got a local authority and local authorities have engineering activities. The roads have got to be built and maintained and the bins have got to be cleaned: all those things are engineering activities. We could ask more of local authorities to supply these sorts of technical work placements. Secondly, we have a vibrant supermarket industry in this country. Supermarkets are engineered processes. It's perfectly possible for Tesco, if it wanted, to create a technical stream to their excellent work placement programme, which would allow young people to see the business end of getting the stuff in, keeping it chilled and refreshed, looking after the inventory and looking after the costing: all those things are engineering activities. So even in deepest rural Lincolnshire, where there may not be obvious industry, and perhaps SMEs are going to struggle, there are some big organisations who could make a difference.

**Q100 Paul Holmes:** Traditionally, FE colleges have taught engineering and schools haven't. We are trying with the 14–19 year initiatives to overcome that, but as the Committee recently pointed out, a school teacher is qualified to teach in FE, but an FE teacher is not qualified to teach in school. What pressure are you putting on the Government to make them change that so that we can make use of FE expertise in schools?

**Professor Harrison:** The diplomas, for example, are taught by consortia, and most consortia have an FE college, and there is a migration of kids, one day a week or one and a half days a week, to the FE college. But it is a one-way migration, and what is tragic is that the technical expertise in the minds of FE lecturers is not making its way back into schools to add to the well-known deficiencies in, for example, physics teaching in schools. There is an issue with transferability of qualifications. There is also an issue with professional development. In FE, the curious thing is that it's mandatory—it's an expectation—that FE lecturers will spend 30 hours a year going through professional development. Yet in schools, in the place where FE teachers can't teach because they don't hold the right certificate, there is no such expectation to do professional development. That is completely hopeless.

**Chairman:** They will if they take any notice of our report, which came out yesterday.

**Professor Harrison:** They would, but the "rarely cover" risk is causing many headaches.

**Chairman:** "Rarely cover" is a disaster to most people.

**Q101 Mr Stuart:** When we went to Holland looking at NEETS a couple of weeks ago, there was a real emphasis on 16–20 to ensure that people received training, education or work, and effectively to pick up those young people who perhaps did not achieve basic maths and other skills during normal school years. You could argue about how important it is to get that right first time, but if you didn't get it right first time, we need a decent process to take people through, and to give them the time to get those skills, so at 20 they may only be at the level where others were at 16. Do you have any thoughts on how to ensure that we lift people up so that they have the basic skill levels to engage with employers and to go on to work in engineering, whether in an apprenticeship, or in higher education?

**Paul Jackson:** In many cases, it is that connection with what it can do for them in future when they have struggled with a more academic route, and the relationship to career opportunities. Picking up Paul's point about using the maths, and concreting, or whatever it was, those kinds of relationships is incredibly important. It is also important that in professional development we have development of the skills related to the subject—those subjects are moving quite rapidly—and the skills related to teaching. That is something, whether it is in schools or FE colleges, that is not enshrined in thinking at the moment, and it needs to be.

**Chris Kirby:** There is a thread coming through all this, which is that whatever the learning issue, as far as engineering is concerned, the key seems to be motivating people to engage. It is equally true of someone who is 20 and coming back to learning when they realise that they want to live their life in a particular way, and someone who is seven and looking ahead to life, and thinking what interests them. Motivation is a key issue at all stages. I want to pull back to a comment that was made earlier about teaching engineering in schools. At least in theory, not even the engineering diploma does that. It uses engineering to teach a variety of things, and one of those things is engineering, but it does not teach engineering in the FE way, as in preparing someone for a career. I am not necessarily saying that we should have a vocational "become an engineer, and be taught it at school" stream, but we need to have an opportunity to use engineering—something that brings together science, maths, technology, design, team-working skills, interest in the world around us, creativity, and so on. That's the opportunity that I want to highlight.

**Q102 Chairman:** You seem to be on a different planet from a mathematician. You seem so bubbly. You have lots of people wanting to do BEng in engineering. Why is that? We have received really good evidence from the mathematicians, but they seemed rather down about the possibility of getting more people into maths, and feeding them into engineering. You seem to be pretty positive about everything.

**Professor Kutnick:** The statistics show that there has been a consistent supply of people at HE level going into engineering. The number has been fairly

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constant. There has been a slight dip, but it has been fairly constant over the past 10 or 15 years. There is a big concern about a growing demand at the mid and low technical levels. There are problems there. Who goes into engineering? Research basically shows that, if a close relative has been an engineer, that seems to be one of the critical routes for how people go into engineering. The people who try to go into engineering without having had exposure to it before constitute a small group, and therein lies some of the rub. Engineering is quite an important subject given its role in society and economic generation. If the parents do not understand what is going on in engineering, will the kid say, "I really want to become an engineer. I need to catch up on some maths"? There is a cultural issue. A couple of weeks ago, I was at the University of Hong Kong and talking about STEM subjects and engineering. The flow of people in Hong Kong going into engineering is not a problem, but there is a whole culture of innovation and entrepreneurship whereby the kids have support at home.

**Q103 Chairman:** There are two problems. I don't know whether it is an apocryphal story. When Sir Richard Sykes was provost at Imperial, he said how terrible it was that we could not get enough technicians. Someone asked him how many he trains. There was a deafening silence. Should there not be a relationship between the technician level and the graduate level? After all, a lot of our brightest engineers in the past came through the apprentice route, but saw no limit to their ambition.

**Chris Kirby:** If I understood him correctly, Tony made the point about the need to raise the overall achievement level in maths across the entire school population, not just the high achievers. I made a note of it because it is a wonderful approach. It would benefit engineering and maths. It would benefit people individually in all sorts of areas of life. The band of people beneath the highest achievers is something on which we need to focus.

**Q104 Chairman:** Is there a chink in your optimism, Peter, in the sense of that familiar link you talk about as being a spur to taking up engineering? Is that why you have so few females in the engineering profession?

**Professor Kutnick:** Probably. There is also formality in the way, usually at secondary level, that maths and science are taught. It tends to put girls off. The primary career aspirations and the engagement in environmental issues have high girls' enthusiasm. There is a real cut between primary and secondary in the way in which matters are handled. It is also interesting that a high proportion of ethnic minorities—for lack of a better term—go into engineering. That probably comes from having the support of a very strong family background.

**Professor Harrison:** The reason why we are bubbly is that we could argue that our time is coming. As a society, we face issues of energy, climate, food and water, which are big engineering challenges. For the

first time in a long time, engineering is starting to feature in the political landscape, and we welcome that. That is cheering us up. We have a real role to play in schools. We have stuff on the mainstream curriculum, which is also cheering us up. We have some particular weaknesses, which you have highlighted. The first is that currently, unless a young person has an engineer as a close role model—probably a family role model—they are unlikely to elect for engineering. That means that we will struggle to get the engineers and technicians whom we need to solve the big problems. The second thing is that only 1% of engineering apprentices are women, only 4% of the profession are women and 13 or 14% of engineering undergraduates are women. We have not done enough as a profession to make a valid case to half the population that there is a role for them in it. If we are going to have our day as engineers, we are going to have to fix that gender issue.

**Q105 Chairman:** Is it better in places such as France and Germany?

**Professor Harrison:** No, it is quite consistently awful, particularly in developed countries. That maps on to the attitudes young people have towards science. The international studies suggest that in developed countries, young people, be they women or men, are enthusiastic about science, but don't want to be scientists or engineers. In developing countries, they are as enthusiastic about learning science and engineering, and being scientists and engineers, as they are about the general subject. It is something to do with the culture of developed countries.

**Q106 Paul Holmes:** Is the 13% of female undergraduates in engineering an onward curve compared with 10 years ago?

**Professor Harrison:** It's falling. It's bad and it's getting worse.

**Chairman:** Annette, do you want to say anything about women in engineering?

**Q107 Annette Brooke:** I feel I should, but you will notice I have been so quiet. I have obviously come from a background that does not want me to engage fully, although I do have A-level maths and am not entirely out of this. The labelling and compartmentalising that starts with girls is so difficult. I suppose that hearing you talk makes me think that maybe we do need to get that enthusiasm at primary school level, otherwise it is probably too late. What concerns me, hearing you all talk, is the issue of getting the right content, even in the diplomas. My one question is whether you are going to have maths and physics specialists teaching within the diploma. Do you see that in the future, or will it be more craft-oriented?

**Professor Harrison:** The bulk of engineering diploma teaching in schools is being carried squarely on the shoulders of design and technology teachers. That is partly because they are there, and partly

because of the very real fact that although there is a definite link between the physics curriculum and the engineering diploma curriculum, there aren't enough physics teachers. The proportion of science teachers who have a physics specialism is 19%, and they are overwhelmingly in the top league-table schools and very absent from any schools in challenging circumstances. Right now, bless them, the D and T community is carrying it. The difficulty is that D and T is a very broad church. The number of teachers who have the required subject knowledge to teach the engineering diploma is probably 1,000 out of the 20,000 D and T teachers in the work force. At the moment, we are getting away with it by having a good spread of dedicated D and T teachers who are taking on this extra burden. As the popularity of the diploma and the BTEC rise, the system will start to creak and groan. At that point, for it to succeed, maths and science colleagues will have to make a contribution.

**Chairman:** I will call you in a second, Peter, because David wants to join in.

**Q108 Mr Chaytor:** Can I just build on that and pick up on Chris's earlier point about the nature of the diploma being not to train future engineers, and on the dangers of early selection. In view of what Matthew said about the high dependency on design and technology teachers, is it possible for the diploma to do the general job of raising interest and enthusiasm for engineering principles among all young pupils, while identifying and motivating those who will go through to the higher levels and take on careers?

**Chris Kirby:** We're quite early in the diploma process, but my experience, from the teachers and young people engaged in the diploma I have spoken to, is exclusively positive, in terms of motivating young people to engage who might otherwise not have done. That relates to the hands-on element of the diploma, the link to what they are doing in science and maths, their general social skills and their willingness to partake in learning anything. My impression so far is that it will have very positive effects broadly, and undoubtedly it will take people through to the higher levels, as universities are already seeing that it has the potential to deliver some good quality candidates into HE, for example.

**Professor Harrison:** I think that it can inspire the mass of kids and prepare the minority who will go forward into engineering, because those who have decided that engineering is for them, often because of family connections, are very careful about the additional and specialist learning they take. They choose that very carefully and build themselves up. They build up the momentum towards a Level 3 qualification in engineering, a degree or an apprenticeship and so forth. For those who just find it fun, it is a great way to spend two or three options after year 9. They get a much wider choice of what they do with their additional and specialist learning. They can do well in the diploma, which can sit alongside a wide range of GCSEs, and come out of school with a nice mix of technical and academic

skills, having enjoyed the process. In a sense, the correct criticism of the diploma is that they are terribly complicated beasts. They really are. There are lots of bits to them. There is an advantage to that, which is that they can be tailored quite precisely to a person's needs.

**Q109 Mr Chaytor:** But if there is this high dependency on D and T teachers, what about the relationship with the D and T curriculum? Is there a blurring between engineering and D and T in the curriculum and, if so, is that a good thing?

**Professor Harrison:** In a sense, it is a good thing from the point of view of the student's experience, because there will be more consistency across the week, so it will make more sense to them. I see a particular risk, as the D and T teachers I meet day in, day out are the dedicated ones and the high-skilled ones. They are volunteering, or being put on the diploma, because they are dedicated and high-skilled, and as a result they are less available to teach, say, resistant materials at Key Stage 3, so I fear that a distraction for them means a lowering of teaching quality elsewhere in the school.

**Q110 Chairman:** Is D and T male-dominated? When I go into a school, I always think of a D and T teacher as a middle-aged man in a brown overall.

**Professor Harrison:** Yes, in certain product areas. For example, systems and control is overwhelmingly male. In resistant materials, which also brings in aspects of textiles, jewellery and other creative subjects, we see a lot of very able women D and T teachers. Of course, in food there is the opposite problem, as it is female-dominated. Across the piece, however, there's no problem.

**Professor Kutnick:** Can I pop a couple of our bubbles here. With regard to how you get into the diploma or the BTEC, we know particularly from science education studies that careers advice in schools is abysmal for any sort of science, maths or engineering orientation. Kids will pick up from that charismatic teacher who has some ideas, but unless the teacher has ideas and can integrate engineering concepts into their teaching at the lower level, that increasing number that we would like to have (come into engineering) will potentially be lost. That is not to say that it is all bad. Ken Mannion, in particular, in his work at his centre for science education at Sheffield Hallam University, has been working with teachers, particularly science teachers, to try to integrate their knowledge of engineering into—well, into the teachers themselves, so that when they give advice to the children they at least have some bit of engineering that comes in. There is hope, but you also have to look at the greater context in which people make the choice.

**Q111 Mr Chaytor:** In terms of the diploma and future training needs, are the Training and Development Agency for Schools and Lifelong Learning UK doing enough to prepare for the future of teaching the diploma?

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**Professor Harrison:** My view is that they've done the basic spadework. The diploma support website is very good, and it's got some great funded material—the stuff that was paid for. It is very informative, with lots of nuts-and-bolts guides, so that teachers can work their way through the diploma system and understand how to deliver it in their own school. However, we are not seeing very many teachers uploading their own stuff. It has yet to become the next stage, which is a forum for sharing practice. The other good thing is that there are accredited professional development courses—Edexcel offers one at Level 5—for diploma teachers. But they are very new, and we have yet to see how many, if any, teachers are taking those up. The spadework has

been done. We have created some good infrastructure, but unless it gets used and school leaders feel able to let their teachers out to make use of it, it will not make a difference.

**Chairman:** I am sorry, I have to pull the plug. We have a slightly shortened session today, and people are keen to see what the Prime Minister and the leaders of the Opposition parties are up to. I thank you. You can tell from the lively debates in the last session and this session that we have very much enjoyed it. It has been too brief. Can you remain in touch with the Committee? People always think, when they get back to their workplace, “Why didn't I ask that question? Why didn't they ask that question?”, so could we remain in contact? Thank you very much; we have learned a great deal.