Response to the call for evidence on computing in schools for the Royal Society State of the Nation Project from: Members of the Technology Mediated Learning Research Group, King's College London Department of Education and Professional Studies

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Introduction

This response has been compiled based on our experience of the following:

1. Researching ICT and computing in Education since the beginning of computers in schools (BCS, 1969). Contributors are also members of the following professional organisations which involve computing in schools and the training of teachers to teach computing in schools:
    a. International Federation of information Processing Working Groups 3.1 on Informatics and ICT in Secondary Education and 3.3 on Research into educational applications of information technologies;
    b. IT in Teacher Education (ITTE) – UK wide association for ICT in Teacher Education
    c. NAACE (National society for ICT in Education)
    d. British Computer Society
2. Running a secondary PGCE Course in ICT and computing since 1996.
3. Running a conversion post-graduate Diploma course for redundant secondary teachers to retrain to becoming IT and Computer Science Teachers (1986 – 1995)
4. School visits and teaching observations as PGCE tutors in London, researchers and external examiners in various parts of UK.
5. Our experience of teaching ICT and computing in schools and university: One of our group taught ICT in school until 5 years ago; another taught computing in schools in the 1980s. Some of us retrained teachers to become IT and computer science teachers.
6. Members of the British Computer Society's expert panel on computing in schools since the early 1980s (MJC and BB).

In addition to comments based on our experience and anecdotal evidence we have also:

1. consulted our current cohort of PGCE trainee teachers (n = 28) on our ICT and computing programme
2. drawn on some preliminary date from the IRIS Project (http://iris.fp-7.org/about-iris/) in which King's STEG group is a partner. The IRIS project is investigating factors influencing recruitment, retention and gender equity in science, technology and mathematics higher education. IRIS collected data by means of an electronic questionnaire to first-year STEM students in five European countries during the period March-June 2010 and received a total of around 6277 responses. In the

STEG group at Kings we are starting to analyse the UK data which includes some responses (relatively small number-about 30) from computing students. There are plans to follow up this questionnaire with focus groups and further questionnaire surveys. We hope to ensure that computing is examined in detail in this project and that computing-specific issues are identified.

3. reviewed evidence from our previous cohorts of PGCE trainee teachers who provided written evaluations and contributed to focus group meetings during their courses.
4. Producing the Open University pack for ICT in IT which was used for in-service training of 60% of all practising IT and Computing teachers in England during the early 1990s.

We think that the issues that have led to: *plummeting levels of applications to study computing at university; a dramatic fall in the numbers of students studying ICT and computing at GCSE and A level and the growing concern within the community that the way that computing is presented at school through the ICT / computing curriculum and associated qualifications is extinguishing young people's enthusiasm for computing* are complex and interrelated. Fundamentally the problem at school level has arisen from two sometimes conflicting needs.

1. The current ICT/computing curricula in schools.
2. The requirement for all teachers to use ICT in their teaching and for pupils to use ICT for learning-sometimes referred to as ICT across the curriculum (ICTAC).

These two aspects of school have been competing for curriculum focus, resources and teaching time for many years. We think that both of these needs are important and deserve ongoing support and development. In recent years however ICT/computing curricula have been squeezed and diluted to meet an apparent need to develop basic ICT skills to support ICTAC, lifelong learning and some low-level vocational requirements in business environments. These problems have been exacerbated by other important factors including shortage of specialist teachers, assessment requirements, schools' needs to meet targets as will be outlined below.

1. Is computing a discipline, in the same way that mathematics, physics, chemistry are?

Computing was established as a discipline in schools during the 1960s in a similar way to mathematics, physics, and chemistry (BCS, 1969), with both substantial theoretical and practical components of the curriculum. However, unlike mathematics it is very broad and has been changing rapidly so that new computing-related courses are frequently being developed at university level. Computing also encompasses many applied elements that more closely resemble engineering as a discipline than mathematics, physics, and chemistry. The summary of the 1989 ACM report (http://cs.gmu.edu/cne/pjd/GP/CompDisc.pdf) was a good introduction to the nature of the discipline at university level. Defining disciplines and specifying curricula at school level are challenging for all subjects but particularly so for a discipline like computing which is evolving so rapidly.

2. Is programming a fundamental form of literacy for the modern age?

Comprehensive programming involves the study of logic, structures, underlying software coding, and complex handling and interpretation of information in different interactive environments; i.e. digital

literacy (see 3 below). Having some understanding of what makes computers work in different ways helps people to understand their capabilities and limitations, and understanding the complexity of large -scale information and information processing enables people to make best use of the pervading Internet resources which are part of all our lives. Without this knowledge there is the danger that people will assume that computers are more capable than they are and therefore people will only function in an IT world at a basic and disadvantaged level. For example our earlier research with 10 to 11 year-olds revealed that they believed computers had magic qualities or human characteristics (Webb 1996).

Programming also enables students to develop thinking and problem solving abilities but how well these transfer to other aspects of learning and life probably, like with the teaching of mathematics, depends on whether students are specifically encouraged to think about their wider application.

3. What purpose should the teaching of ICT and Computing in schools serve?

The curriculum for ICT and Computing, like that for other subjects should serve two main, sometimes conflicting purposes: 1) to enable all students to understand fundamental ideas and develop skills that they need in life beyond school as explained above; 2) to prepare students for further study in the discipline to become the next generation of experts in the IT field.

In addition ICT in particular has to enable students to develop a "digital literacy" that they need to study other curriculum subjects as well as to function as citizens. With respect to this "digital literacy" ICT has similarities to English in the curriculum but whereas teachers of other curriculum subjects are generally well equipped to support the development of traditional literacy across the curriculum these teachers are less capable of supporting the development of digital literacy across the curriculum. Therefore the best model for development of digital literacy at present involves a combination of specialist ICT lessons and cross curricular work preferably with good collaboration between ICT specialist teachers and other subject teachers.

4. Is the teaching of ICT (and accompanying qualifications, such as ICT GCSE) fit for purpose for all students? What should be done to address this?

Our experience suggests that the teaching of ICT is very variable in the UK. Many teachers are devising interesting schemes of work and developing innovative teaching especially at KS3 but also at A-level. Our experiences of 14-16 teaching of ICT / Computing in schools around London supports the findings of Ofsted reports from 2005 to 2008 "The past few years have seen a sharp increase in the number of students taking Key Stage 4 vocational qualifications instead of GCSE ICT. Although these vocational courses are the equivalent of up to four GCSEs in other subjects, they offer limited challenge in ICT." (OFSTED 2009 p. 5).

Focus group discussions with our PGCE cohorts over the last two years especially towards the end of their courses when they had developed a good understanding of teaching revealed significant concerns about these vocational ICT courses and the way they were advised to teach them. Specifically whereas the trainee teachers believed that it was important for their students to understand concepts underlying

the work that they were doing the assessment requirements of the courses did not encourage this and the trainees were encouraged to just get the students through the coursework.

Teaching of ICT / Computing at KS3 varies depending on whether the teachers are specialists or not and whether the scheme of work can be used effectively by non-specialists. Our trainee teacher are required to observe ICT teaching before they apply for the PGCE so they visit a range of schools and a significant number reported observing ICT teaching by non-specialists where they felt that the teachers had little understanding of the concepts they were teaching.

5. **Is computing and ICT best 'taught' in classrooms or 'learnt' by other means? How do learners learn computing and ICT skills?**

Computing and ICT are not substantially different from other subjects in this respect. Learning takes place in a variety of formal and informal settings. The myth of the abilities of "digital natives" to develop extensive and sufficient ICT capabilities through their everyday activities has been largely refuted (Bennett, Maton et al. 2008; CIBER 2008). Recent research in Europe (Livingstone and Haddon 2009) shows that 75% of European children use the Internet but they "vary considerably in their ability to access, judge and navigate among the range of media contents and services. Many have a weak understanding of how contents are produced, disseminated, financed or regulated, undermining decisions about trustworthiness, authenticity or risk." (p. 25). Furthermore, a survey of 144 1st year King's College Dental undergraduate students in 2009 showed that less than 40% of them knew sufficient basic IT skills, like "drag and drop', 'file saving etc.
There is evidence from our own experience with young people in schools as well as from research (e.g. Ito, Horst et al. 2008) that some young people become very interested in the creative possibilities of ICT and Computing and develop excellent skills in particular areas, e.g. games programming. However even this minority of students will almost certainly not develop the broader understanding and range of capabilities that they are likely to need to build on their expertise without substantial good teaching. Therefore we think that computing and ICT need to be taught in such a way that all young people are enabled to benefit from learning with digital technologies but also they can build on their experiences outside of school and develop according to their own capabilities and interests.

6. What motivates students to study computing? Is it what they learn in school or something else?

A rough pole of our current cohort of PGCE trainees (n = 23) on our ICT and computing programme showed the following reasons for choosing to study computing at university

- They liked ICT at school = 8
- They were good at computing = 5
- They liked programming which they did outside school = 5
- They studied A- level computing at school and liked it so did a degree = 3
- They chose to study computing at university fairly randomly without much thought but then found they liked it = 4
- They wanted to *teach* computing/ICT =3
- Their parents wanted them to do a degree that would lead straight to a profession = 1

N.B. Our current cohort of PGCE trainees on our ICT and computing programme comprises 28 and of those 18 studied computing courses at university, 5 studied ICT /information systems and 5 did courses that covered both computing and ICT /information systems
Interestingly none of this group volunteered that their teachers had influenced or inspired them and when asked only 2 felt that their teaching at school had been good. This contrasts with data from the IRIS Project where teaching in school appears to have a particularly strong influence on students' choices of university courses across STEM subjects as a whole. We have not yet analysed these data in relation to specific STEM subjects although we intend to do so in future.

7. How is computing presented at school, and is there a variation between schools? Why?

A PhD study of 50 secondary schools by Beauchamp in 2005 at King's College (Beauchamp 2005) showed that the level of resourcing in schools for the teaching of computing varied enormously between a school with 1200 pupils having a computing department of 5 ICT staff plus an ICT technical support team and a curriculum advisor for other teachers, to a school with a similar school roll having one single teacher who was expected to teach ICT as a subject to all year groups, maintain the school network, support other teachers using ICT across the curriculum and provide all the technical support as well. Similar imbalances were found between the computing/ICT curriculum. Many schools did not even teach computing to all year groups, and had only 20% of the timetabled sessions for the teaching of mathematics. This research and other similar studies has shown that there is a vast variation across schools with many schools trying to teach ICT as a subject merely through its use in other subjects. The consequence of this is a very uneven opportunity for school students to learn computing and/or to be inspired to take it up as a career. All of the schools that we work with have been specifically chosen because they have good (or at least reasonable) teaching of computing and ICT. Even within some of these schools not all of them teach computing up to A-level.

It seems that girls-only schools are less likely to offer A-level computing. While our PGCE cohort is usually roughly evenly split across genders, the current cohort reported that the majority of the ICT departments they have been sent to on placement are male-dominated. The women on our current PGCE cohort feel that the teaching of ICT/ Computing in the schools to which they have been is often oriented towards male interests.

8. **Who is teaching computing, and what qualifications do they hold? Are teachers sufficiently supported with subject - specific CPD? Are there enough specialist teachers? Why do they leave/join the profession? What are the barriers to improving the situation?**

In our partnership schools there are specialist teachers teaching ICT/ Computing at GCSE and A-level but we still find teachers with no qualifications in ICT/ Computing teaching at KS3.

The teachers who have qualified through our PGCE ICT and computing Programme have all studied computing or ICT to at least first degree level. For example, our current cohort comprises 28 and of those 18 studied computing courses (e.g. Computer Science, Multimedia Computing) , at university, 5 studied ICT /information systems and 5 did courses that covered both computing and ICT /information

systems (e.g. business computing). Recruiting suitably qualified graduates with good subject knowledge to our secondary PGCE ICT/ Computing course has been relatively easy since the recession but prior to that it was quite a challenge to get enough good graduates. For example, in recent years we have interviewed university students about to graduate in ICT–based courses wishing to come on our PGCE course who did not have enough knowledge and expertise in the subject to be able to teach it at GCSE level, let alone A-level (they were not accepted onto our course) so when the jobs market picks up we may have more problems in having enough sufficiently qualified students.

In discussion with other ITE Providers it has become apparent that some of them are not able to insist on the high standard of qualifications and good subject knowledge that we expect of our entrants and therefore some have to spend much time in a very intensive PGCE developing subject knowledge. There are some 2-year PGCE courses to try and address this problem

There has been very little subject-specific CPD until recently -the computing sessions led by CAS are welcome and the support of the British Computer Society. The lack of a professional organisation for specialist teachers of ICT/ Informatics / Computing has been a problem and still is, although the BCS has now widened its membership to include computing teachers. The Association for Computing and IT Teachers (ACITT) of which MJC was the president, used to provide a network of professionals supporting each other but when it was subsumed into NAACE this specific support was lost. Currently, because of its diverse membership NAACE is unable to provide a useful professional service for specialist teachers of ICT/ Informatics / Computing.

9. Why do some universities prefer their undergraduate applicants to have studied mathematics rather than computing at A-level?

Universities prefer students to have studied Maths at university rather than Computing for two reasons. First- tabula rasa- universities would prefer that students do not have to unlearn misconceptions and habits acquired in Computing- this is essentially a criticism of the out-of-dateness of the Computing curriculum and its teaching- and in such a fast moving subject where universities are in the forefront this is an inevitable situation. (Nevertheless - much better that students study computing at school and go on to computing at university than do neither!) Second- A-level maths is an important qualification for university computing courses, not because of the particular content of A-level maths but because of the facility with mathematical language and thinking that will be acquired.

We are not sure that this preference for studying A-level mathematics, Languages and other sciences rather than computing is still stated by many universities although of course mathematics is likely to be a requirement for computer science courses and universities cannot require their students to have studied A-level computing because many schools do not offer it.

10. What are the perceptions of computing and ICT amongst learners, teachers and head teachers? How can information, advice and guidance be improved?

In our research into ICT in schools, e.g. a recent study of Thin Client technology in schools by Cox with KPMG (Becta, 2006) and two large literature surveys of ICT and attainment (Cox and Abbott, 2004) and ICT and pedagogy (Cox and Webb, 2004), we have found that many learners, teachers and even head-teachers still perceive computing as a narrow set of ICT skills such as emailing, word-processing and searching the Internet and do not understand the deeper subject on which those are based. For example, the majority of teachers who use ICT in schools and this is still a significant **minority** of teachers, may be competent at using power point presentations in their lessons, and using word-processing for assignments but may have not understanding or expertise in using databases, computer based modeling, or measurement and control (in the case of science teachers). The Thin Client study of 12 secondary schools and 12 primary schools in 2007 found that less than 20% of teachers were using ICT in their teaching even though these were high ICT using schools selected for the study.

A PhD study (Burstow 2006) focused on the perceptions of computing and ICT in schools. Specifically a study of the introduction of cross-curricular ICT in one school, between 1998 and 2000, showed a wide range of perceptions among staff (based on multiple interviews with approx. 16 individuals). Perceptions when analysed related to 10 "critical themes" (and comments were recorded for a continuum of responses from positive to negative for each of these):

ICT as an agent for change
The attitude of the teacher to their pupils
The attitude of the teacher to their colleagues
The attitude of the teacher to computers
Issues of perceived complexity and stability (or lack of it) in ICT
Computer confidence and usage
ICT and the effect on classroom control
The establishment of the subject department (in the use of ICT and other new developments)
Perceptions of how ICT relates to the subject
The "Right" person: relating teacher personality to ICT facility

Further analysis of this data suggested a number of "macro-themes", three of which were:
Those who are unsure of themselves in normal classroom situations will tend to be slow adopters of ICT.
Training that takes place away from the working environment, especially when it is not followed up with guided practice, is not likely to result in lasting change. (Supporting and extending Joyce and Showers work (Joyce and Showers 1980))
There is a given level of departmental maturity, in terms of staffing and working practices, that is needed before a new development, like ICT, can be successfully introduced. (Burstow 2006)

Headteachers' perceptions of ICT is less well observed in this study, being more anecdotal and based only on observation of four headteachers (in the subject schools). Perceptions of these headteachers varied from several of Hawridge 's rationales (Hawkridge 1990) – especially the social, vocational, pedagogic (particularly for the first of the three heads) , catalytic and cost-effective to a more prosaic "marketing" rationale where having a lead in ICT implementation was seen as an advantage in promoting the school to prospective parents (these last three are typical of the approach of the second

of the three head teachers). The third Headteacher viewed ICT developments as an expensive impediment to core learning and reduced the funding of ICT accordingly. The fourth head (appointed at the time of Thomas Telford schools publication of the online GNVQ in ICT) favoured ICT as a means of rapidly increasing the 5A*-C pass rate and encouraged the growth of an IT department at the expense of cross-curricular ICT.

The changes listed above took place between 1995 and 2005 and illustrate the key role played by the head in a school's development. Critical factors, relating to advice and guidance, that emerged from this research were four:
The reaction and interaction of the people involved.
The personality and approach of anyone in a "facilitator" role.
The availability of the technology.
The influence of external factors – including the senior leadership team of the school

Although the awareness of the significance of IT and computing amongst head teachers has improved, there are still resource and time-tabling conflicts with other subjects. Some head-teachers in our studies have said that they cannot increase the time-table for the teaching of computing and ICT because there are no other subjects which they can cut back. Similarly for those head-teachers trying to increase the use of ICT across subjects, they have reported the difficulty of providing enough resources to cover both aspects: ICT across the curriculum and ICT/Computing as a subject (Cox, 2005).

11. Are these issues unique to the UK?

The issues discussed above are not unique to the UK; see for example Wilson et al. (2010) for concerns about computer science in schools in the US. Our experience through IFIP also suggests that there are concerns across Europe about computing/ICT/ informatics curricula and about ICT in the curriculum and in other parts of the world. However it would be a mistake to assume that the situation across all countries is similar or that the factors affecting ICT/ Computing in schools is similar. Various different curricula models are in operation, teacher education models vary and the degree of central specification varies. Furthermore colleagues in other European countries feel that their subject "informatics" presents a clearer description of this subject at school level than the term ICT which is used in the UK alone to label both the specialist subject of study and the use of digital technologies across the curriculum. When the UK government education minister introduced the term ICT this caused enormous confusion amongst teachers and was strongly opposed by ACITT at the time. Sadly the concerns expressed to ministers by ACITT and other professional bodies has now been shown to be true, with the curriculum for ICT and computing being interpreted very differently amongst schools, teachers, colleges and industry.

One common factor that may have led to a decline in computing/ informatics is the drive to establish basic digital literacy to support learning in all subjects. This seems to have focused attention on basic ICT skills at the expense of real understanding of computing/ informatics concepts.

12. What can universities do to improve the situation?

Universities can provide clear information on their websites that helps prospective students to understand the range of different fields of research and courses on offer. Interestingly Kings has just renamed its department *informatics* in order to reflect the greater range of fields of study it offers beyond traditional computer science (see http://www.kcl.ac.uk/schools/nms/informatics/prospective/). The student ambassador scheme in which King's participates, in which undergraduates undertake teaching placements in schools, has certainly helped some King's students to decide whether they want to teach. In addition it is hoped that this scheme also provides role models for school students and opportunities for them to develop better understanding of what further study of computing entails.

Universities can also provide guidelines to GCSE, A-level and Vocational exam boards as to the meaning of computing and ICT and to encourage a more consistent and high standard across all exam boards. Universities UK can also provide more effective monitoring of existing university computing/ICT courses of which there are over 400, to ensure that similar standards are reached across the whole sector even if the focus might vary across institutions.

13. Is there a case for curriculum reform? Is this the barrier?

There is certainly a strong case for curriculum reform because of all the issues we have reported on above. The quote from a letter received by us from one of our ex-PCCE trainees, an inspiring and enthusiastic teacher who left after about three years of teaching to take a job in software development in 2007 sums up the problems quite well:

I left teaching because I couldn't balance my social time and work time effectively and I hated my subject. I don't hate ICT in principle but I thoroughly disagree with the government's interpretation of ICT (surprise, surprise!). Where the government have given a broad and interesting scope for ICT at KS3 which I thoroughly enjoyed teaching and developing lessons for. At GCSE level, the boundaries are narrow, skill-focused, ill defined and uninspiring. Teaching pupils about batch processing and how to make a business letter is not what I call "Applied ICT". There have been some interesting developments especially with OCR National Diplomas in ICT (the new GNVQs) but the level of intellectual effort is quite inconsistent.

We agree that the curriculum at KS3 is no barrier to interesting work and innovative teaching. Problems that have arisen at KS3 are due to teaching by non-specialists as explained above and in some schools by bringing vocational qualifications in at KS3 thereby focusing students purely on business applications too early in their learning which can stifle their interest and creativity.

We have seen many changes to courses at GCSE level over the last 15 years and not all have been beneficial. The new GCSE in Computing is a welcome introduction. Problems with the KS4 curriculum stem from several interrelated issues:

1. Vocational courses that are skills-based and fail to promote understanding of concepts
2. The need for schools to keep improving grades has led them to push many students through easy vocational qualifications in ICT
3. An over-emphasis on business applications of ICT

4. A conflict between the educational value of practical project /course work and the need for reliable assessment.

Practical Project work has always been considered an important component in ICT / computing/ informatics courses. At its best it provides students with opportunities to work collaboratively and creatively to solve interesting real problems and we have seen examples of such work usually conducted with classes before they embark on their GCSE work.

Going back ten years or so GCSE courses generally included an open-ended project that students completed individually and it was assessed as 30-50% of their overall grade. This had advantages and limitations. Advantages were in opportunities for creativity and engagement with solving a real problem and the motivation that some students developed. Disadvantages were 1) the challenge for teachers in identifying and supporting a diversity of problems and 2) perceptions over the unreliability of this form of assessment. These perceptions were probably the main reason for the change from open-ended projects to structured coursework and controlled assessments. The current "assessment climate" is probably not conducive to reintroducing very open projects at GCSE level. Therefore controlled assessments are probably the best alternative. The OCR controlled assessments, for example, encourage collaborative group work at the research stage. Therefore using this model pupils can learn through problem based learning in groups prior to taking the controlled assessments.

We need to re-examine vocational qualifications and their method of delivery to determine whether an alternative can be found to pupils plodding through lots of skills-based coursework without developing understanding. This problem is much broader than the ICT/ Computing curriculum and solutions may be found from cross–European comparisons: see for example the draft literature review of: "Qualifications, learning outcomes and competencies: a review of European divergences in vocational education and training (VET)" at http://www.kcl.ac.uk/content/1/c6/01/57/15/literaturereview.pdf in which this broader problem is discussed. The following quote from this review supports our concerns: "while in Germany, France and the Netherlands, VET involves different types of knowledge (task-specific, occupational and industrial) to underpin practice in a relatively broad occupational field, VET in England is aimed at acquiring (ever narrowly defined) task-specific skills with no or little underpinning knowledge" (p.4).

14. Is there a need for an increased recognition of ICT and computing as part of the T in STEM, through representation in STEM forums and increased funding?

Yes. Science and mathematics have a long history of teaching and research which underpins the teaching of these subjects whereas technology and hence computing follows a roller-coaster ride because the boundaries and fundamental hardware and software associated with it are always changing. Yet, computing is underpinning more and more, science, applied mathematics and technology. As, quoted many years ago by a famous pioneer of computers in education, Bill Tagg of the Advisory Unit in Hertfordshire, the machine extended our physical might and produced the industrial revolution; Computing/IT extends our intellectual might and is producing the IT revolution. If we are to maintain our lead in science, mathematics and technology we need to invest in computing and ICT which will underpin and strengthen this lead.

15. What happens if we do nothing?

Spiral of decline in computing through low numbers of computing undergraduates leading to low numbers of well qualified teachers leading to even less inspiring teaching. This in turn will reduce our national expertise in the field in which we are currently leading the world, particularly in innovative uses of ICT in education and innovations in IT fields. We shall be overtaken by other developed countries who are already investing much more in this subject domain.

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