Computing at School: Stimulating Computing Education in the UK

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ABSTRACT

In this paper, we present the development of Computing At School (CAS) [1] , a UK membership association established in 2008 to promote and support the teaching of Computing and related disciplines in UK schools. Its membership is broad and includes teachers, parents, examiners, university faculty, professional societies and industry.

CAS was born out of a serious concern that many students in the UK are disengaging from Computing as a discipline due to the emphasis given to ICT, a compulsory subject in UK schools. Aspects of the curriculum have conspired to make ICT as sometimes taught in schools appear dull and pedestrian, focusing on a superficial understanding of software without any emphasis on foundation knowledge or developing computational thinking.

The goal of CAS is to put the excitement back into Computing at school, as well as to influence Computing education policy in the UK, especially improving the wider perception of the discipline and its position within the STEM subject area. In this discussion paper, we will present the rationale and motivation for CAS, its range of initiatives to support teachers and drive curriculum change, as well as its advocacy at national policy level. Furthermore, we discuss how the UK Computing education picture compares with the USA and the rest of Europe.

Categories and Subject Descriptors

K.3.2 [**Computers and Education**]: Computer and Information Science Education—*Computer science education, curriculum, literacy*

Keywords

Computer science education, Computing, ICT, STEM, UK education policy

[1]Further information about CAS and its activities can be found here: `http://www.computingatschool.org.uk/`

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1. BACKGROUND

First, a note on terminology: a traditional description of Computing presents a spectrum of activity ranging from theory at one end to practice at the other. It also describes aspects ranging from hardware through to software, and from the study of computers and computation per se through to applications-oriented study [21]. In this paper, we will use *Computing* to represent the cognate area commonly called Computer Science or Informatics at degree level, due to the nomenclature used in secondary education in the UK. While "digital literacy" is a crucial skill for all, it is important to clearly distinguish Computing from the more vocational and skills-based ICT.

There have been significant changes to compulsory education in the UK over the last 25 years, which have resulted in Computing essentially disappearing as a curriculum subject for under-16 year olds, being replaced by Information & Communication Technology (ICT). In 1988, the National Curriculum was introduced into England and Wales; followed shortly afterwards by an A-Level in ICT for 16-18 year-olds (an A-Level in Computing had been available since the early 1970s [6]). In the mid-1990s, ICT became a compulsory subject up to age 16 and effectively the fourth core subject in the school curriculum. In addition, the early 2000s saw an large increase in the availability of vocational qualifications in ICT; these are still popular with schools and focus on developing skills in software packages as well as other ICT soft skills. However, concerns have been expressed that ICT lessons are "boring" [2] and do not engage or enthuse students [3, 5], as well as focusing too much on basic digital literacy. With ICT now being embedded across the curriculum at primary schools in the UK (ages 5-11), pupils in secondary school (ages 11-16) increasingly find ICT unstimulating if they already have the skills that are being taught. However, this focus on ICT in schools has meant that there are often no options for pupils who wish to study Computing, and often mistakenly believe that they are one and the same subject. Hence, with pupils not having a clear understanding of what Computing actually encapsulates as a academic discipline at this stage of their education, this seriously hinders its selection at a later stage. The majority of students leave school actively disliking what they mistakenly believe to be Computing [3].

In addition to the existing curriculum provision, in order to be able to offer more Computing in schools, we also need teachers who are qualified to teach the subject. Initial Teacher Training (ITT) in ICT in England and Wales does

not generally include a focus on Computing topics, rather on ensuring that newly-qualified teachers can deliver the National Curriculum in ICT. While Scotland has a different education system that does incorporate aspects of Computing in teacher training (as well as aspects of Computing in its new Curriculum for Excellence [16]), curriculum change across the UK is problematic without refocusing teacher training.

Until recently, the UK teacher trying to incorporate Computing into secondary schools at ages 11-16 would have felt alone and unsupported, even with recent initiatives to encourage school pupils to consider aspects of Computing, such as CS Unplugged [19] and CS Inside [11]. Both of these initiatives focus on exciting and ways of introducing computational principles to children and young people. The Computer Science Teachers Association (CSTA) in the USA (supported by the ACM) provides a model for the UK of what a Computing subject association could provide for the teaching community. Furthermore, in Israel, the teaching of computer science at high school level has been in place nationally for many years [14], with a well-developed curriculum and teacher training programme underpinned by active pedagogical research. This has provided a useful model for other countries to explore, when faced with the situation of re-establishing Computing in the curriculum. It is against this backdrop that the need for a national organisation to promote Computing education in the UK was identified. As with many such ventures, it started as a small group of individuals with a passion for Computing and a vision for bringing the excitement of Computing back into schools. This paper details the rationale for the Computing at School (CAS) association, as well as describing what has been achieved and what it aims to do in the future.

2. THE CAS MISSION STATEMENT

Computing has transformed the way we communicate, work and play in recent decades. However, it is not obvious to most people that it is a broad, deep, exciting, and fertile discipline. Its full potential can only be realised through great creativity and ingenuity in working with concepts, theories and challenges. It has also been a powerful source of new ways of thinking that have influenced many other fields, as diverse as biology, mathematics and philosophy. Computing at School (CAS) aims to support and promote this vision of Computing in UK schools, by providing opportunities and resources to help all educators and learners to better understand, use and develop Computing in a variety of activities and fields.

3. THE RATIONALE BEHIND CAS

Computing at School (CAS) evolved in early 2008 as a small group of academics and teachers who shared a common dissatisfaction with the lack of Computing studied at school and hence the number of students coming through to study Computing at A-Level and degree level at university. It was born out of excitement with the discipline, combined with a serious concern that many students are being "turned off" Computing by a combination of factors that have conspired to make the subject seem dull and pedestrian. Its primary goal is to put the excitement back into Computing at school.

CAS is fundamentally a grass roots organisation, whose energy, creativity, and leadership comes from its members. It is a collaborative partner with BCS, The Chartered Institute for IT through the BCS Academy of Computing (the learned society in the UK dedicated to promoting Computing as an academic discipline [2]), and has formal support from major industry partners, including Microsoft Research and Google. Its membership is open to everyone, and includes teachers, parents, governors, exam boards, industry, professional societies, and universities.

CAS seeks to work at many levels, including:

- Directly supporting Computing and ICT teachers by providing them with teaching material, training, local hubs, newsletters and the opportunity to interact with like-minded colleagues.
- Acting as a Subject Association for Computing teachers.
- Working at an institutional level, by encouraging curriculum change and qualifications development.
- Advocacy at national policy level.

4. THE PROBLEMS

One of the key problems facing Computing in the UK is that students are not attracted to the subject at age 16 where Computing qualifications exist, because they do not know the difference between ICT and Computing. They may have been put off the former by an excessive focus on digital literacy, to the detriment of understanding why and how we use technology and as well as any deeper comprehension of Computing's mathematical, scientific or engineering foundations.

It is essential that students are introduced to Computing principles at a young age, so that they begin to develop computational thinking [25], problem-solving and analytic skills, as well as being able to link the technology that surrounds them to its underpinning formalisms. There are many teachers who are keen to offer this in school but who are invariably constrained by the contrasting demands of compulsory vocational qualifications in ICT. Nevertheless, there are also many teachers who do not have the academic background or experience to teach Computing, and who would need significant training if Computing was to be offered as a mainstream subject to students from 11-16 years.

We summarise the current state of play at the key stages of secondary education in the UK:

Key Stage 3 (11-14): The compulsory programme of study in ICT has failed to develop imaginatively, with the cycle of updates lagging far behind where the curriculum ought to be to support, engage and enthuse the incoming "digital natives". The majority of curriculum is heavily oriented towards IT; for example, presentation software, desktop publishing and basic webpage development, as well as skills that have already been developed.

Key Stage 4 (GCSE, 14-16): A similar situation applies to the Key Stage 4 (GCSE) curriculum in ICT. The ICT syllabi are often boring and de-motivating and there is only one pilot GCSE in Computing (running

[2] `http://academy.bcs.org/`

from September 2010), as well as an iGCSE (International GCSE) in Computing but this has only recently been available to state schools.

14-19 Diploma From September 2008, the Secondary Curriculum Reform has introduced a new concept of curriculum planning in which students are taught the core within employment sectors (lines of study). The IT and Telecommunication sector is represented by e-skills UK, which canvass IT employers' view and have produced the subject criteria for the IT Diploma. Early experiences have indicated positive responses from students due to the problem solving emphasis and the opportunities for extended projects. The principal learning outcomes of the Diploma, however, revolves round Business, Technology and People. The choice available for the majority of the specialist learning option are restricted by the availability of technical courses available.

Key Stage 5 (A-Level, 16-18): There are a range of AS/A-Levels in ICT but these contain very little Computing. Examination boards do also offer syllabi in Computing but these have to follow a prescribed and constraining subject core shared with ICT AS/A-Level, which has distorted the current AS/A-Level Computing syllabi (2000-present). In February 2005, the issue was addressed by the Department of Education, who granted AS/A-Level Computing its own subject core for the development of revised AS/A-Level Computing syllabi for teaching from September 2008. However the Key Stage 3 and Key Stage 4 ICT curricula are missing out many of the fundamentals that are required to develop and inspire a future cohort of A-Level Computing students.

In previous years, A-Level Computing was not considered to be sufficiently aligned with university courses in Computer Science to be given valued status. However, recent developments in A-Level curricula (for example, AQA), as well as new advice from leading universities in the UK [22] has started to change this. Nevertheless, the recognition by universities of A-Level Computing remains a challenge, invariably preferring Mathematics [3].

The numbers of students studying Computing A-Level (16-18 years) has decreased over previous years, with a 13.7% decrease from 2009 to 2010. Figure 1 shows the decrease in numbers of students taking Computing A-Level from 2004-2010. Williams reports that as the professional workforce is forecast to grow at four times the average for the UK and it will need 50,000 new entrants over the next five years, this situation is of great concern to the IT industry [23]. Numbers of students taking Computer Science degrees in higher education are also decreasing rapidly: UK university applications to read Computer Science are down over 60% since 2000 [7, 3] and there is a high drop out rate [18, 26].

Furthermore, Clark and Boyle describe how the content of the Computing curriculum changed in the UK in the mid-1980s when personal computers became available and students needed to be taught skills in the use of computers and software rather than underlying computational principles [8]. From this point on, there was a shift in emphasis

[3]For example, Cambridge University: `http://www.cscubed.org/entry/`

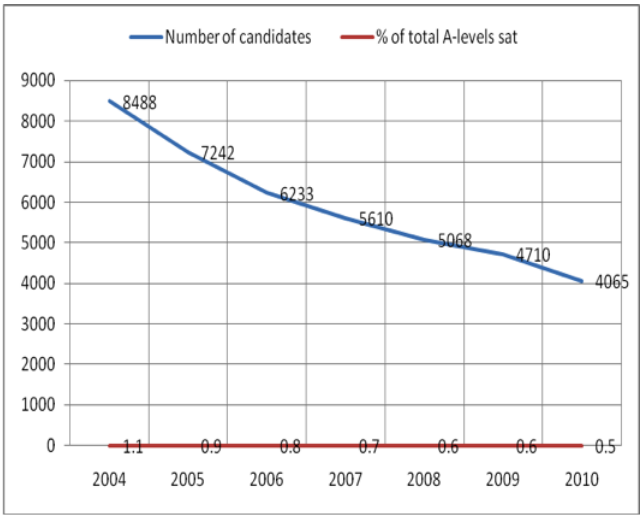

Figure 1: Numbers of students achieving A-Level Computing in the UK [23]

to ICT in schools, while Computing was delivered as a specialist course at A-Level only.

CAS offers support to teachers as well as shared good practice, and through this national group, teachers can find ideas for engaging and enthusing students in Computing. However, CAS is much more than a subject association for teachers, as supporting and training teachers is only one part of its role. Advocacy at national policy level to incorporate Computing into key national science and education strategies is crucial if the subject is to grow and meet the demands of the digital society and information economy in which we now live.

5. CAS ACTIVITIES

To further the aims of CAS, we operate on a number of levels, interacting both nationally and locally. Many of the national initiatives have been focused on contributing to key policy consultations, including:

- The Royal Society's Call for Evidence on Computing in Schools [4], an 18 month consultation that will report back in Autumn 2011. The Society is looking at the way that Computing is taught in schools, to address growing concerns that the design and delivery of the ICT and Computing curricula in schools is putting young people off studying the subject further. The effect on the UK economy of the dwindling enthusiasm for Computing/ICT in schools is also being explored, together with the need for more specialist teachers and development of qualifications that can motivate and inspire the next generation. CAS (through the BCS Academy of Computing) have been heavily involved in the Royal Society's consultation process, with its contribution highlighted as one of the ten key submissions [3].
- The House of Common's Education Select Committee Inquiry and Call for Evidence into the English Bac-

[4]`http://royalsociety.org/education/policy/computing-in-schools/`

calaureate [4], particularly focusing on its purpose and benefits, as well as the choice of subjects included in the E-Bac. The English Baccalaureate was announced by the Education Secretary in September 2010. It is awarded to students who achieve A* to C in the following GCSE or iGCSE subjects: English, mathematics, two separate sciences or double award science, history or geography and a language.

- Department of Education's Call for Evidence for the National Curriculum Review in England, especially the position of ICT and Computing with regards to the other core subjects. The government has said that English, mathematics, science and physical education must remain compulsory for children of all ages, but the review panel has been asked to look at what subjects should be compulsory for pupils of different ages, as well as the content that should be taught in them. CAS (again with the BCS Academy of Computing) have submitted a significant consultation report for the National Curriculum Review [5].

- Developing a Curriculum for Computing [5] for Key Stage 3 and 4, produced by a working party within CAS. This describes in concrete terms what a Computing curriculum at school might look like. It uses the same structure as the National Curriculum Programmes of Study: importance of the discipline; key concepts; key processes; range and content; and level descriptors. This work complements the National Curriculum Review and E-Bac consultations.

- Preliminary work in supporting Initial Teacher Training in the UK, especially promoting the development of ITT for Computing, as well as highlighting its position within the strategically important STEM portfolio [12, 13].

- Three successful CAS annual conferences in England, with a inaugural 2011 CAS conference in Wales. The popularity of these events (c.250 attendees) is increasing every year, with more teachers signing up to become CAS members. The CAS annual conferences provides a fertile environment for teachers to connect with other teachers, as well as highlighting national and international initiatives.

- Sixth form conference across the UK, entitled "Inventing the Future", to coincide with National Science & Engineering Week. These conferences provide an opportunity for students to gain insights into the real world of Computing from people working in research, universities and industries.

- Working with national examination boards, such as AQA, OCR and WJEC, to further develop Computing and ICT qualifications in the UK, especially at Key Stage 3, 4 and 5.

- Linking with existing national initiatives; for example in Wales, CAS are working with Technocamps [6], a £6m project funded by the European Social Fund through the Welsh Government to target the Convergence areas of Wales, to provide extra-curricular activities in Computing and STEM, as well as teacher CPD and driving curriculum and policy changes.

- Involvement in a range of science communication and public engagement activities (and other less formal activities [20]) to promote Computing to a wider audience and attempt to change the seemingly poor perception of it as a rigorous and stimulating science discipline [10, 17]. Examples include: National Science & Engineering Week (organised by the British Science Association), STEM Ambassador scheme, Researchers in Residence (supported by Research Councils UK), "I'm A Scientist, Get Me Out of Here!" [7] (an award-winning science engagement activity supported by the Wellcome Trust), Public Engagement Ambassador scheme (supported by the UK Higher Education Funding Councils) and other national and regional science communication activities.

A range of initiatives have also been developed by CAS which encourage teachers to learn from each other, access support for their Computing teaching, as well as building a community of practice to inspire and empower. For example:

- Local CAS hub meetings are held after school for groups of teachers in the areas across the UK to discuss Computing teaching issues. Guest speakers are invited to share their own areas of expertise. To date, there are now 17 hubs across England and Wales.

- 'TeachShare' online events to enable Computing teachers to share best practices from their teaching or experiences. This is done using web conferencing software providing virtual spaces for teaching sessions.

- Continual Professional Development (CPD) for teachers across the UK through face-to-face sessions on the more advanced theory topics in the A-Level curriculum, together with blended learning courses on teaching programming. Supporting teacher CPD is a key CAS activity.

6. FUTURE DIRECTIONS

The need for more Computing education in schools is an international one. The Computing education community, already well established, is turning its attention to schools. In the UK, for example, the University of Kent, with a thriving Computing education department, have spearheaded the development of Greenfoot [8], a development environment for Java which is becoming increasingly popular in UK schools. Other UK initiatives include the work done at Queen Marys University in London on Computer Science for Fun (cs4fn) [9] who have a team of academics providing inspirational outreach to large numbers of school children across the UK. The Digital Schoolhouse project [10], initiated in the USA and now emerging in the UK, and gives inspiration for teachers wanting to introduce Computing at primary level (7-11 years).

[5] Available from: `http://www.computingatschool.org.uk/data/uploads/ComputingCurric.pdf`

[6] `http://www.technocamps.com`

[7] `http://imascientist.org.uk/`

[8] `http://www.greenfoot.org`

[9] `http://www.cs4fn.org`

[10] `http://www.digitalschoolhouse.org.uk`

Qualifications are being established in the UK to enable students to take Computing as a separate subject at school. For thirty or forty years, there has been an A-Level qualification in Computing for 16-18 year olds; numbers had fallen dramatically but are back on the increase. In 2008, the core content for this subject was rewritten at national level to distinguish it clearly from the equivalent qualification in ICT. For the first time, in September 2010, a GCSE qualification in Computing has been launched for 14-16 year olds and this is proving popular during its pilot period. Work in accrediting qualifications that are specific to Computing is essential in encouraging teachers and students to regard the subject as a separate discipline. CAS will continue to support the development of appropriate Computing qualifications and programmes of study across Key Stages 1 to 5. A number of sixth-form conferences have been held across the UK to further stimulate the interest of 16-18 year olds in studying Computing. Many of these have been organised by CAS and are sponsored and supported by leading industrial and research organisations. Advocacy at national policy level is improving, with the Welsh Government's Deputy Minister for Skills speaking at the inaugural CAS Wales conference in July 2011. Furthermore, CAS members in Wales are contributing to the new Welsh science framework to be published in Autumn 2011, to highlight the importance of Computing in underpinning modern scientific research and supporting future innovation, R&D and economic renewal.

In the future, CAS will continue to present their case at a national level to give Computing its own place in the curriculum for 11-16 year old students. Furthermore, we are targeting continuing professional development of teachers by establishing a catalogue of courses accessible to teachers at different levels. Key also is the development of a set of resources for teachers to use in teaching Computing. Supporting and developing newly-qualified teachers is essential and they will continue to put pressure on the government to fund and support the teaching of Computing as a subject in its own right. The UK government is aware that more highly-qualified graduates are needed to teach Mathematics and Science [13] and is prepared to support this through a new National Scholarship Scheme [12]; the message is being heard that Computing also is within this subject group and it is essential that we can train teachers specifically qualified in this discipline.

Nevertheless, there is still significant work to "market" Computing as a rigorous and stimulating discipline and change its seemingly poor public perception. The terminology problem ("*Computer science is no more about computers than astronomy is about telescopes.*", Edsger W. Dijkstra) can also hinder what people perceive to be Computing, as well as the wide range of Computing careers. However, the development of computational thinking, problem-solving and analytical skills, are key skills for everyone.

While many of these issues are not unique to the UK [1, 24], other countries do teach Computing within school, including the USA [9], Israel [15], Lithuania, Canada, Finland and Germany. We are starting to learn from these countries, so we look forward to the continued development of CAS and promotion of its activities on a local and national level. We believe it is of strategic national importance that all children have the option to study Computing in school between the ages of eleven and sixteen.

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