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Computing Science

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Introduction

More than six years have now passed since the centenary of Alan Turing's birth in 2012. At that time one of the important things to say about Computing and Information Systems education in Scottish Schools was that it was on the cusp of change. Alan Turing, the 'father' of modern computing, was a little known British genius, who is commemorated in one of the leading schools of Informatics in the UK, at the University of Edinburgh (The Turing Room). Turing's contributions to the country's future, both as a computer scientist of genius, and a wartime code-breaker, are seminal. Yet, despite this, it continues to be the case that his reputation does not extend far beyond Computer Science. In a way, a similar fate has befallen Computer Science education itself. As an area of study, it continues to be somewhat neglected beyond the universities, yet there remains little doubt that the skills of Computing Science (CS), Computing education and computational thinking more broadly, are of considerable and increasing importance for Scotland's economic and scientific futures. Therefore, it is crucial that new curriculum developments in this field support and enhance the talents and abilities of all Scotland's young people.

Achievements and challenges for Computing Science education

Any account of the situation and progress of Computing Science in schools must be seen in the context of the broader changes within Scottish education since the introduction of a Curriculum for Excellence (CfE) into Secondary schools in 2010-11 The CS Exemplification project, supported by the British Computer Society (BCS), the Royal Society of Edinburgh, and Education Scotland, heralded changes from the 5-14 ICT curriculum to the new Computing Science in the Technologies curriculum of CfE. Starting in 2011, and ending in 2013, it helped to exemplify exciting new approaches to teaching Computing Science concepts and programming skills in the later years of the

Broad General Education. It made use of many new visual programming environments for novices, such as Scratch, Snap and AppInventor, and emphasised a creative approach to teaching CS.

During the first Computing At School Scotland conference (2014) in Microsoft's Edinburgh Office, many Scottish Computing teachers gathered together to examine the project outcomes, and new learning and teaching materials. Subsequent conferences in Glasgow, Dundee, and Edinburgh Napier University, brought together a growing number of Computing education initiatives. Recognising a pressing need for further professional learning to support Computing teachers, the Scottish Government funded a national programme of professional learning and networking for computing (PLAN C) between 2013 and 2015. During this project, over fifty Lead Teachers worked together with two National Project Officers to develop an understanding of research informed teaching practices specifically for CS. They then shared this by establishing twenty-four PLAN C hubs across Scotland where colleagues in local areas could meet, share their own experiences and explore the new approaches to learning and teaching.

In 2015, Skills Development Scotland launched a Skills Investment Plan for Scotland's ICT and Digital Technologies Sector. Their Digital World campaign helped to raise wider public awareness of the opportunities enabled by studying CS. The pace of developments accelerated further still in 2016 with Education Scotland's release of 'How Good Is Our School?4' which highlighted the underpinning nature of Computing Science for digital skills focusing on 'Increasing Creativity and Employability'. In the same year Computing At School Scotland and BT launched the Barefoot project for Primary schools in Scotland, Education Scotland, together with Hewlett Packard and Intel, started the Digital Schools Award for Primary schools.

Finally, some five years after Turing's centenary, Education Scotland released revised experiences and outcomes and benchmarks for the Technologies curricular area. The Centre for Computing Science Education was also established at the University of Glasgow. This will eventually become a central hub for the development of innovative approaches to Computing Science teacher education, a key focus for other strategic initiatives to support CS education, and a place where people can come together to help shape the future of the subject in Scotland.

Notwithstanding these developments, the greatest challenge presently facing the subject is teacher supply. The recent report by Computing at School Scotland (2016) has provided much insightful analysis that helps in understanding this issue.

	2005	**2007**	**2009**	**2011**	**2013**	**2015**
Number of FTEs	802	779	726	675	649	598
% Change compared to 2005		-3%	-9%	-16%	-19%	-25%

Table 53.1 Computer Science Teachers in Scottish Schools from 2005 to 2015 (Computing At School Scotland, 2016)

In terms of Computing Science as a specialism, the most significant parameter is that the number of Full Time Equivalent Computing teachers in Scotland has decreased. Table 53.1 show this decline with data collected through Freedom of Information requests from all 32 local authorities (30 satisfactory responses, one did not breakdown the figures by school and one is thought to be inaccurate). This was cross-referenced with Information provided by the Scottish Qualifications Authority (SQA), the General Teaching Council for Scotland (GTCS), and the Scottish Government. In 2015, there were only 598 Full Time Equivalent (FTE) teachers, which is lower than any other specialist area in the Sciences, other Technologies or Mathematics. This has major implications for the health of the subject going forward, with some local authorities having fewer teachers than schools, particularly in rural or remote areas.

It's interesting to note that although the total number of pupils on the Secondary school roll fell by 11%, since 2005, there was a 25% decrease in the number of Computing teachers. By comparison, the numbers of teachers of English, Mathematics and Physics decreased by 4%, 6% and 10% respectively. This suggests that pupils' access to

Computing education in general, and CS in particular, narrowed. Over the last decade we have reached a position where nearly one fifth of Scottish schools (2016), spread over half of the local authorities, have no computing specialist actively teaching classes. With a further quarter of Secondary schools having only one Computing teacher, it is clear that guaranteed access to a coherent experience of Computing Science in the formal curriculum is less certain now than it was before the introduction of CfE.

It would be tempting to assume that schools, local authorities and the wider educational establishment no longer consider access to Computing Science education as a priority for pupils. However, nearly half of local authorities reported difficulties recruiting suitable candidates for CS teacher vacancies. Even where a post has been filled, there have been many instances where only one or two suitable candidates applied. Over half of local authorities have also had difficulties sourcing suitable Computing supply cover. The number of new teachers entering the profession is down by 67% on 2006. As a further illustration of the lack of supply, only 20 newly qualified teachers joined the teacher induction scheme in 2014 and 2016. The Scottish Government has set specific and increased targets for Computing teachers since 2014, but with only two Initial Teacher Education institutions in Glasgow able to recruit enough suitable applicants, more will have to be done to attract new entrants into the profession.

Computing Qualifications

Historically, Computing education has centred on developing problem-solving skills by encouraging learners to apply knowledge, understanding and practical skills. Computing included the study of the professional, social, ethical and legal implications of its use, as well as the clear and concise communication of computing concepts using appropriate terminology. Starting at Intermediate 2 level (SCQF level 5) and upwards, options were provided in Artificial Intelligence, Computer Networking, and Multimedia Technology. The Higher qualification (SCQF level 6) in Computing also encouraged awareness of technological developments and progress, factors affecting system performance, and issues of syntax and semantics. Mandatory topics of study included data representation, computer structure, peripherals, networking and software. Learners also acquired knowledge and skills in developing software using a high-level programming language. The course encouraged them to make judgments, assess and compare ideas, and evaluate data. In Advanced Higher Computing, these ideas and skills were extended through investigation and analysis. It aimed to equip learners with skills to design and implement a solution to a significant computing problem of the learners choosing. The course focused on the software development process, looking at software development languages and environments, high level programming languages, and standard algorithms with Computer Architecture replacing the Multimedia Technology optional unit. Students were assessed using both written and practical assessment instruments.

Running in parallel to the Higher Still Qualifications in Computing was 'Computing Studies' (introduced in 1984 and phased out in 2013). This was offered at Standard Grade (SCQF levels 3-5) and Intermediate 1 level (SCQF level 4). The key aim of this course was to provide knowledge and experience of 'the technology that lies at the heart of modern society'. It covered information technology concepts, the practical operation of hardware and software, and the awareness of how computers affect our work, home and leisure activities.

The new subject that was developed as part of CfE was called 'Computing Science' and combined concepts and skills from both the previous Computing and the Information Systems suite of qualifications. This emerged in response to a build-up of concerns with both Computing and Information Systems and Computer Studies in Scottish schools (see below). It was designed to combine the best aspects of both current subjects. Computing Science develops a range of computing and computational thinking skills, including skills in analysis and problem-solving, design, as well as modelling, developing, implementing and testing digital solutions, across a range of contemporary contexts. In addition, the developers claim that it takes account of modern technologies and development methodologies related to software and information systems. The revised versions of these qualifications, currently being phased in, have been re-organised around four areas of application of Computing Science- Software, Web and Database Development, and Computer Architecture. A timed practical task carried out in class, that samples skills across Software, Web and Database Development will contribute to 30% of the overall award with another 70% from the written exam set by the SQA. At Advanced Higher level, this will change to a 40% weighting for the practical task and 60% for the final written exam.

Rationale for Computing Science

There has been a developing consensus that courses in Computing and Computer Studies needed substantial revision to meet the needs of students and educators for the 21st century in Scotland. For example, one point which was made by teachers was that this suite of subjects did not concentrate enough on the main concepts of Computing Science, and concentrated too much on hardware and systems that dated quickly and became obsolete. Similar issues were raised about the English qualifications by the Computing at School Working Group in 2012, before the establishment of separate groups in Scotland, Wales and Northern Ireland. In many ways, both of these criticisms echoed the more detailed range of concerns raised by the Royal Society of London about the state of Computing in schools across the UK (Royal Society, 2012). While the data and evidence presented in that report was based significantly on the English context, it also aligned with findings from interviews (conducted for this chapter) with other leading and informed figures in the field of Scottish education and teacher education.

Another issue that prompted the move was the confusion between 'Computing' – the science discussed above - and the use of computers in a wide range of settings to manage a vast array of activities and communications – often referred to more recently as 'Digital Literacy or Digital Skills'. This has been widespread amongst parents and pupils, schools, local authorities, teaching colleagues and government ministers. One of the consequences is that Computing Science itself has been often overlooked in this confusion. This had implications in the past for policy, teacher education, and pupils' future lives and careers. This confusion has been more firmly addressed, with the new Technologies Experiences and Outcomes and benchmarks in the Broad General Education phase (Nursery to 3rd year of Secondary school) and the Computing Science qualifications in the Senior Phase (4th to 6th year of Secondary school). However, it is important to continue to 'dis-aggregate' the term from wider notions of 'Digital Literacy', so that 'Computing Science' can achieve some distinctive recognition as a central scientific discipline in its own right. Although members of the Computing community are more keenly aware of the distinction, further work will need carried out to develop understanding more widely both within education and public life generally.

Learning from international perspectives

Looking at Computer Science teaching internationally, it is still clear that other countries with a similar population size and GDP to Scotland have undertaken initiatives in the field of school Computing Science education from which Scotland could learn as it develops its Curriculum for Excellence. Israel, for example, undertook a major review of Computing in school in the 1990s. It now has one of the most rigorous Computer Science high school programmes in the world. Stephenson *et al.* (2005) consulted an international panel of Computer Science educators, including those in Scotland, Israel, and Canada. They concluded that when a country is developing a new curriculum it is essential to ensure that it meets key criteria. These include ensuring that: there is a link between the outcome required and the strategies used; change is driven by "real learning needs and not politically manufactured needs"; the context of larger social and economic forces is considered. Furthermore, stakeholder agreement, adequate resources and a long-term vision were also cited as being central to success in curriculum improvement. Hazzan, Gal-Ezer and Blum (2008) developed a model to encapsulate the current high school computer science curriculum in Israel that is built on these criteria. Their 'Four Key Elements' are: a well-defined curriculum (including written course textbooks and teaching guides); a requirement of a mandatory formal CS teaching license; teacher preparation programmes (including at least a Bachelor's degree in CS and a CS teaching certificate study program); and research in CS education (Hazzan, Gal-Ezer and Blum, 2008 p.281). The new curriculum has been in place since 1995, and is taken by 10,000 – 20,000 students.

New Zealand is another successful 'Computer Science country' with a population size and GDP comparable to Scotland. In 2008 two influential reports appeared (Grinsey *et. al.;* Carrel *et. al.*) that influenced a revamping of its school curriculum in Digital Technologies. The curriculum from 2011 has an explicit strand called 'Programming and Computer Science'. Having established the importance of programming skills, the curriculum designers are now shifting their focus to the infrastructural issues of creating suitable materials and developing teacher education. All seven of the major Computer Science departments have been involved in the process, as well as in the revised teacher education that will support it. These examples help to provide a 'template' for some of the issues and challenges that Scotland still faces as it strives to implement and support its new Computing Science qualifications in Curriculum for Excellence.

Conclusions

We are now over six years on from the centenary of Turing's birth, and Computing Science Education has passed a turning point in Scotland. There is good reason for optimism, with the new Centre for Computing Science Education in Glasgow striving to promote the subject in new and innovative ways. Revisions and improvements to the existing Computing Science qualifications are coming on stream, and the new emphasis on the rigour of the scientific aspects of the discipline will help young people to establish the foundations of successful careers. Educating new generations in computing science will assist in creating more informed citizens and help develop Scotland's economy in changing and challenging global conditions. However, the challenges of meeting specialist teacher supply, developing suitable innovative CPD with a pedagogical focus, and creating new and exciting teaching and learning materials remain. All these need to be addressed if Scotland is to truly bring its Computing Science education on to the world stage in the 21st century. Turing, we hope, would have been proud of the progress that has been made in Scotland. We hope to honour his memory by continuing the pace of improvements in the coming years.

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