Technocamps: A Decade of Supporting Computer Science Education in Wales

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1. INTRODUCTION

In the early 1980s, the BBC Micro was introduced to schools throughout the UK as part of the BBC's *Computer Literacy Project*; before long they were in 80% of UK classrooms [Vasko and Dicheva 1986]. By encouraging young learners to experiment with computers, a generation of creative (and computational) talent was spawned. Applications in the UK to study computer science at university hit a peak, with computer science graduates helping computers come to dominate every aspect of our lives.

In the 1980s, computer studies was a popular subject in schools across the UK. The ubiquitous presence of the popular BBC Micro[1] – which was of little practical use unless you were able to program – saw a large proportion of school children learning the fundamentals of programming in a curriculum which included a variety of complementary topics such as hardware, software, Boolean logic and binary number representation.

Fast forward 30 years and the situation is very much different. The computer is no longer a novelty; children now typically spend more time in front of a computer screen than a TV screen at home, but like the TV, their interest is restricted to using the computer, not in experimenting with it. Computer studies in school – since the late 1990s generally named *Information and Communications Technology* (ICT) – has evolved into IT studies with an emphasis on digital literacy and "office productivity" skills – significantly more mundane than the social networking and gaming for which many pupils use their personal digital devices. In 2012, a report indicated that a full two-thirds of ICT teachers in the UK do not have a relevant qualification but may have

[1] https://en.wikipedia.org/wiki/BBC_Micro

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moved into the role of ICT teacher simply by being sufficiently digitally literate [Royal Society 2012]. The situation is worse in Wales, where this figure rises to 75% [General Teaching Council of Wales 2008], with ICT perceived to be a low-priority discipline in schools. Applications to study computer science at university slumped in the early part of the millennium – especially amongst females – and many of those who started a university computer science degree course found themselves dropping out during the first year, surprised at what computer science is and what studying it entails.

By the 1990s, the emergence of pre-installed software – specifically office productivity software such as word processors and spreadsheet programs – meant that computers were no longer predominantly machines that needed to be programmed in order to do anything useful or interesting. Less and less time was being spent in the computer studies classroom on thinking about and writing programs, as basic digital literacies and IT user skills became regarded as the priority. However, as interest in viewing the computer as a creative tool waned in favour of using it for more mundane tasks, various problems were being created, which were highlighted in two independent national enquiries in 1997. Both reports concluded that "*Information Technology*" in UK schools was in a primitive state and in need of attention and major investment. In line with the Stevenson Report, computer studies evolved into a new subject whose name was coined in that same report: *Information and Communications Technology* (ICT). Over the decade starting in 1997, the UK Government invested over £3.5bn in ICT in schools through various initiatives such as the National Grid for Learning and the New Opportunities Fund [Doughty 2006].

By 2000, ICT had permeated both primary and secondary school curricula. The emphasis was on developing the children's IT skills and digital literacy in an honest attempt to address the increasing need for digital competencies amongst the general public. However, despite enormous government-funded ICT initiatives, various reports throughout the decade identified problems with implementing government policy on ICT educational reform [Opie and Fukuyo 2000; Ofsted 2001; 2002; 2004; Loveless 2005]. Younie [Younie 2006] summarises the problems identified by these reports into five key areas, including management, teacher training and competence, as well as impact on pedagogy. The ICT curriculum in Wales [Welsh Government 2008], while generally viewed to be more flexible and less prescriptive than the equivalent subject in England, exhibited many of the same issues [Estyn 2013; 2014]. A full two-thirds of ICT teachers in the UK do not have a relevant qualification but may have moved into the role of ICT teacher simply by being sufficiently digitally literate [Royal Society 2012]. The situation is worse in Wales, where this figure rises to 75% [General Teaching Council of Wales 2008], with ICT perceived to be a low-priority discipline in many schools. Applications to study computer science at university slumped in the early part of the millennium – especially amongst females – and many of those who started a university computer science degree course found themselves dropping out during the first year, surprised at what computer science is and what studying it entails.

A decade later, two high-profile policy reports – one by Nesta [Livingstone and Hope 2011], the UK's innovation charity and one by the Royal Society [Royal Society 2012], the UK's premier science academy – made the very same observations. The report noted that ICT suffers from a poor reputation amongst pupils, parents and industry, who consider it dull and unchallenging and hence a low-value discipline, especially compared to other strategically-significant STEM subjects. With ICT embedded across the primary school curriculum, secondary school pupils found ICT in secondary school neither stimulating nor engaging [Sentance et al. 2012]. The 2011 Wolf review [Wolf 2011] of vocational education for 14-19 year-olds in the UK further notes that the undemanding nature of ICT qualifications in secondary schools is readily exploited by schools: due to a disproportionately high national league table weighting associ-

ated with vocational qualifications, easily-achieved high results in ICT offer a welcome boost to a school's league table position. Furthermore, as ICT is typically presented by schools as their "Computing" offering, students who might otherwise enjoy studying computer science are actively put off from what they are incorrectly but innocently led to believe is computer science [Crick and Sentance 2012; Brown et al. 2013].

Recognising this trend, the Department of Computer Science at Swansea University in the early 2000s started looking into ways to address this issue. Unfortunately, attempts to reach out to teachers in local schools faced great resistance, in part due to their lack of confidence in teaching actual computer science as opposed to developing skills in using specific desktop software packages.

As an alternative route to effecting change and getting into schools, Swansea University created Technocamps[2] in 2003, an outreach programme to bring groups of school children to the university campus for day-long workshops based on selected computational themes to inform them what computing is about, followed-up by support in setting up extracurricular clubs – *Technoclubs* – in the schools. Technocamps proved hugely successful as a local initiative, with many students opting to study computer science at Swansea University claiming to be influenced by Technocamps activities.

Technocamps[3], a university-based schools outreach programme based at Swansea University, was founded in 2003 to address these emerging problems in Wales. We have previously discussed its portfolio of activities in more detail [**?**]; in this paper, we consider the wider impact of the Technocamps project and its potential replicability as a case study of a national engagement model for other countries and regions. We evidence this through the consideration of its measurable effect on schools, teachers and pupils, contextualised by emerging educational (and economic) policy change in Wales, particularly with respect to reform of computer science and digital competencies.

In 2010, based on long-term empirical data regarding its effect on school children's attitudes towards computer science and technology careers – as well as their teachers' – Swansea University was awarded £3.9 million funding towards a £6 million four-year project (with the remaining £2.1 million generated through matched funding from the university) by the Welsh Government under the EU's European Social Fund (ESF) Convergence Programme[4] to run Technocamps as a pan-Wales project with regional hubs at the Universities of Aberystwyth, Bangor and Glamorgan (now University of South Wales).[5] Though focusing on the children, Technocamps also provides "Technoteach" events aimed at up-skilling ICT teachers in Wales. Technocamps has since provided computer science-related activities and resources for tens of thousands of young people across Wales, as well as interacting with hundreds of teachers across hundreds of the nation's schools.

Technocamps is not alone in exploring solutions to the multitude of problems in computer science education in the UK. In particular, in 2008 the Computing At School (CAS)[6] organisation was formed, which has since been recognised as the UK subject association for computer science and a key stakeholder from a policy perspective. Its current membership of over 18,000 teachers and computing professionals work hard to promote the teaching of computer science at school. However, whilst great changes have taken place in England due in no small part to CAS lobbying and on the ground

[2]http://www.technocamps.com
[3]http://www.technocamps.com
[4]http://wefo.wales.gov.uk/programmes/20072013/convergence/?lang=en
[5]As discussed in further detail in Section 3, Technocamps hubs have subsequently been set up at most of the remaining major Universities in Wales, specifically Cardiff University, Cardiff Metropolitan University, and Glyndŵr University in Wrexham.
[6]http://www.computingatschool.org.uk

initiatives[7] – underpinned by generous funding of CAS by England's Department of Education – the wider CAS effect has been less noticeable in Wales, with the rapid curriculum changes pushed through in England in many ways resisted by the Welsh Government.

Wales is one of the four devolved nations within the UK, with its own elected national government fully responsible for its education system. In 2012, the Welsh Government's Minister for Education and Skills publicly acknowledged the importance of computer science education for all – noting the impact of Technocamps – and expressed understanding of the wider educational and socio-economic impact that the government can make with educational reform in Wales. However, with only 5% of the population of England and with its distinct geographical and socio-cultural challenges, Wales presents a variety of unique challenges in addressing curriculum reform. Nevertheless, since 2013 we have seen significant industry and public scrutiny of the relevancy of the school curriculum and the changing skills demands of the wider digital economy, with a range of government-initiated independent reviews of ICT culminating in a substantial review of the wider national curriculum. Wales is thus on the cusp of substantial reform, with Technocamps having a front-line role in the development of a new computing curriculum, as well as supporting the professional development of teachers.

2. THE UK'S FOUR EDUCATION SYSTEMS

The UK consists of four nations ruled by one parliament, with an overall population of 64.5 million: England (population: 54.3 million), Scotland (5.3 million), Wales (3.1 million) and Northern Ireland (1.8 million) [**?**]. In 1997, Scotland and Wales held referendums which determined in both cases the desire for self-government. In the case of Wales, this led to the Government of Wales Act 1998 which created the National Assembly for Wales, to which a variety of powers were devolved from the UK parliament on 1 July 1999 (and again with the Wales Act 2014). In particular, education – which until then was a UK-wide government portfolio (minus Scotland, which for historical reasons has had a distinct legal and education system from England and Wales) – came under the control of the National Assembly for Wales.

Wales is a small nation to the west of England with an ancient Celtic culture and a thriving separate language (with c.20% of the population able to speak Welsh, a member of the Brythonic branch of the Celtic languages). Its south coast became preeminent during the Industrial Revolution due to coal mining and heavy industry; however, Wales is mostly rural and suffers from post-industrial poverty, seasonal employment and the dependence on the public sector for a significant proportion of jobs. The country is sparsely populated with resilience and interconnectedness of the transport infrastructure an issue. Hence its communities – specifically its schools and teachers – suffer from the perils of isolation, like other countries actively addressing the technology skills gap (such as New Zealand [**?**], Sweden [**?**] and Israel [**?**]). Apart from the south east corner (including its capital Cardiff) and the regions bordering England, the rest of the country is formally designated by the EU as a so-called "Convergence area", meaning its per-capita GDP is less than 75% of the EU average.

Politically, Wales became a devolved nation within the UK in 1999. Prior to this, the education system in Wales was essentially identical to that in England and was in a healthy state, outperforming other regions in the UK in the years prior to and immediately following devolution. However, since devolution saw the education port-

[7]Its contributions to the new Computing curriculum in England were recognised by winning the 2014 Informatics Europe Best Practices in Education Award: http://www.computingatschool.org.uk/index.php?id=best-practice-in-education-award-2014

folio transferred to the National Assembly of Wales, it has suffered a rapid decline. Evans [Evans 2015] presents a detailed analysis as to the cause of this, citing a multitude of policy changes and poor interventions, alongside a hard-hitting report from the OECD [OECD 2014].

The UK consists of four nations ruled by one parliament, with an overall population of 64.1 million: England (population: 53.9 million), Scotland (5.3 million), Wales (3.1 million) and Northern Ireland (1.8 million) [ONS 2014]. In 1997, Scotland and Wales held referendums which determined in both cases the desire for self-government. In the case of Wales, this led to the Government of Wales Act 1998 which created the National Assembly for Wales, to which a variety of powers were devolved from the UK parliament on 1 July 1999 (and again with the Wales Act 2014). In particular, education – which until then was a UK-wide government portfolio (minus Scotland, which for historical reasons has had a distinct legal and education system from England and Wales) – came under the control of the National Assembly for Wales, under the direction of the Department for Education and Skills (originally the Department for Children, Education, Lifelong Learning and Skills).

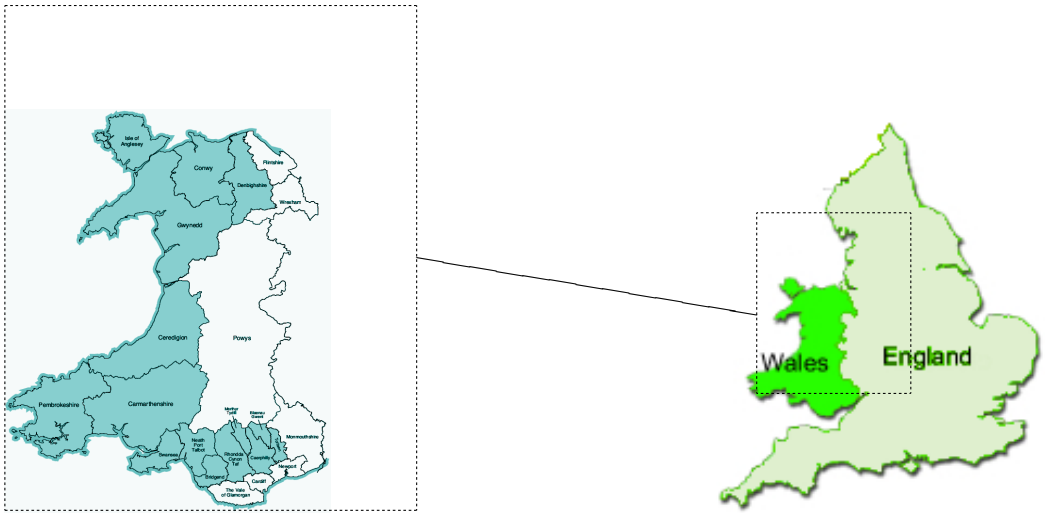
Wales is a small nation to the west of England (see Figure 1(b)). It has an ancient Celtic culture and a thriving language (with c.20% of the population able to speak Welsh). Its south coast became pre-eminent during the Industrial Revolution due to coal mining and heavy industry; however, Wales is mostly rural and suffers from post-industrial poverty, seasonal employment and the dependence on the public sector for a significant proportion of jobs. The country is sparsely populated with resilience and interconnectedness of the transport infrastructure. Hence its communities – and more specifically its schools and teachers – suffer from the perils of isolation. Apart from the south east corner (including its capital Cardiff, with a population of c.325,000) and the regions bordering England, the rest of the country is formally designated by the EU as a so-called "Convergence area" (see Figure 1(a)), meaning its per-capita gross domestic product (GDP) is less than 75% of the EU average.

Prior to devolution, the education system in Wales was essentially identical to that in England and was in a generally healthy state, outperforming other regions in the UK in the years prior to and immediately following devolution. However, since devolution it has suffered a rapid decline. Evans carries out a systematic and detailed analysis as to why this was the case, citing a multitude of policy changes and poor interventions [Evans 2015], alongside a hard-hitting report from the OECD [OECD 2014].

Whilst broadly maintaining the general educational system of Key Stages used in England (see Figure 2), the Welsh Government embarked on a 10-year revolutionary plan including:

— phasing out national Standard Attainment Tests (SATs);
— replacing the early years Key Stage 1 with a learning through play-based Foundation Phase;
— introducing the Welsh Baccalaureate[8] at all levels: an overarching qualification, with a purely practical-based assessment mechanism, incorporating key skills; Wales, Europe and the world; work-related education; and personal and social education;
— emphasising the focus on the Welsh language and Welsh-medium schools;
— addressing the abundance of small schools in the predominantly rural communities throughout Wales;
— tackling deprivation.

[8]http://www.welshbaccalaureate.org.uk/



(a) Convergence area of Wales, which encompasses 15 (out of 22) western councils that do *not* border England

(b) Wales and England

Fig. 1. Maps of Wales and England

Much of this plan was lauded, being learner-focused, placing an emphasis on skills development and ensuring that it is appropriate for the specific needs of Wales. However, since its implementation, it has been criticised for various reasons and by various stakeholders. The then Minister for Education and Skills appointed in June 2010, in looking for the causes of Wales' failing education system, found cause to commission no fewer than 24 costly reviews before his untimely resignation in February 2013 – almost one per month [Evans 2015].

With devolved government comes autonomy over fiscal matters; and the correlation between money and performance is an obvious target for critics, who point to a growing spending shortfall between Wales and England. The average spend per pupil in Wales in 2000-2001 – just after devolution – was more than every region of England apart from the large metropolitan areas of London, the West Midlands and the North West, all of which benefit from their vast economies of scale. However, since then, the gap between the education budgets per pupil between Wales and England has steadily grown by about 1% per year; the figures forecast for 2013-2014 show 13% more being spent per pupil in England than in Wales (£7,533 per pupil in England as opposed to £6,676 per pupil in Wales) [Evans 2015].

Whilst broadly maintaining the general educational system used in England, the Welsh Government embarked on a 10-year revolutionary plan including introducing the Welsh Baccalaureate[9], an overarching qualification, with a purely practical-based assessment, incorporating transferable skills useful for higher education and employment, as well as explicitly using education as a lever to tackle socio-economic deprivation. Much of this plan was widely lauded by key stakeholders, being learner-focused and practioner-led, placing an emphasis on skills development and ensuring that it is

[9]http://www.welshbaccalaureate.org.uk/

Age		Key Stage	Year	Phase
18+	Post-compulsory			Further Education
17-18			Y13 (A-levels)	
16-17			Y12 (AS-level)	
15-16	Compulsory Education	KS4	Y11 (GCSE)	Secondary schools
14-15			Y10	
13-14		KS3	Y9	
12-13			Y8	
11-12			Y7	
10-11		KS2	Y6 (SATs)	Primary schools
9-10			Y5	
8-9			Y4	
7-8			Y3	
6-7		KS1	Y2	
5-6			Y1	
4-5		EYFS	R	
0-4				Pre-school

Fig. 2. Key Stages in the English and Welsh education system

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When establishing a model for viewing school computer science education, it is apparent that there is substantial diversity between school education systems [**?**], and this can create obstacles when trying to understand progress made in one country and potentially replicate it in another [**?**]; this is also pertinent to the devolved (and diverging) educational systems of the UK.

As reported by Hubweiser et al. [Hubwieser et al. 2011], when establishing a model for viewing school computer science education, it is apparent that there is much diversity between school education systems, and this can create an obstacle when trying to understand progress made in a different country; this is particularly pertinent to the devolved educational systems of the UK.

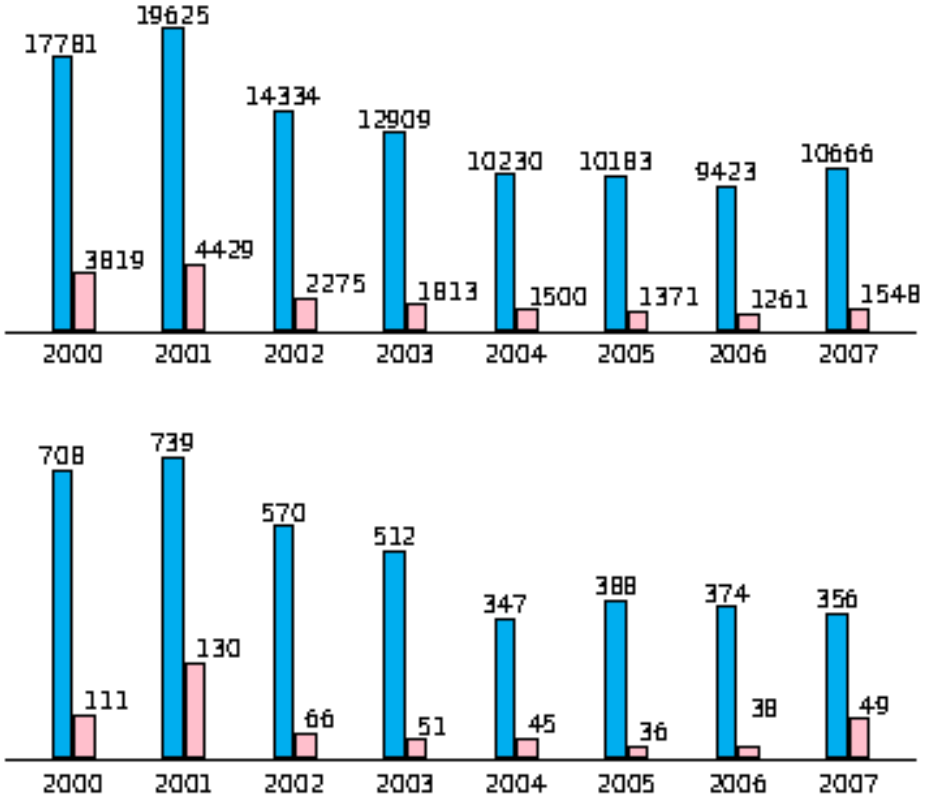

Fig. 3. Applications to University computer science degree programmes in the UK (top) and Wales (bottom), males (blue) and females (pink). (source: Universities and Colleges Admissions Service (UCAS))

3. TECHNOCAMPS

As experienced by other UK universities, the numbers of students enrolling in computer science degree programmes at Swansea University increased through the end of the millennium due to the dot-com boom. However, as depicted in Figure 3, throughout the UK (as elsewhere) the numbers then peaked, and what followed was a steady five-year decline, dropping more than 40% during that period, with the worst effect on the already-dwindling numbers of female students. Even at its peak, more than a third of students who started a computer science degree programme left the programme before their second year of study, citing a mistaken understanding of the subject as their primary reason for leaving (in line with the findings in [Brown et al. 2014]).

In an attempt to address this worrying anomaly, the Department of Computer Science at Swansea University[10] reached out to local secondary school ICT teachers, inviting them to meetings at the university, and offering to visit schools to discuss the subject with the teachers and to give motivational talks to students. Indeed, the Department was invited every year to a number of schools in England to present such talks to school children making their university admissions selections. However, interest locally was more than absent: there was positive resistance to the department giving talks to their prospective university applicants; such activity was typically char-

[10]http://www.swansea.ac.uk/compsci

acterised as merely nakedly "pitching for students." In reality, for reasons explained later which did not apply to teachers in England, teachers in Wales were generally feeling over-burdened and disinterested in exploring any perceptions of inadequacy in the curriculum and their delivery [Crick and Sentance 2012; Boyle et al. 2012; Brown et al. 2014].

As it appeared to be futile to influence schools and their ICT teachers directly, Technocamps was created in 2003 to promote computing amongst their pupils. This was a programme of engaging interactive computational workshops taking place on the university campus whose ultimate aim was to subtly re-introduce computer science into the ICT curriculum by generating the demand from the students. Originally run only at Swansea University, Technocamps hubs have since been created at most universities throughout Wales, offering wide geographical coverage.

Teachers in Wales were happy to "treat" their classes to these "day out" activities; but they were then faced with the prospect of satisfying their pupils' newly-discovered passion for computing, programming and computational thinking [Wing 2008; Calderon et al. 2015] by introducing *Technoclubs* as lunch-time extra-curricular activities in the school. With generous help, resources and guidance from Technocamps – along with the fact that in many cases students appeared to be more technically informed and digitally literate than their teachers [Sentance et al. 2012] – these clubs have flourished, and the impact of Technocamps in changing attitudes in Welsh schools regarding ICT and computing has been widely acknowledged, both by the Welsh Government and National Assembly for Wales (the devolved parliament), as well as the teaching community in Wales.

Since 2000, Swansea University (as elsewhere across the UK) suffered a steady decline in the number of students enrolling in computer science, with the worst effect on the already-dwindling numbers of female students. In an attempt to address this worrying anomaly, the University reached out to local secondary school ICT teacher. However, there was positive resistance; for reasons explained later which did not apply to teachers in England, teachers in Wales felt over-burdened and disinterested in exploring any perceptions of inadequacy in the curriculum and their delivery [Crick and Sentance 2012; Brown et al. 2013].

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3.1. The Technocamps Programme

As indicated above, Wales provides a variety of major challenges – political, geographical, socio-economic – in reforming its curriculum to re-introduce computer science into the space currently populated by ICT, with its preponderance of IT skills development. Whilst there is clear industrial support for educational reform which notes the importance of high-value digital skills for long-term economic renewal for Wales as an agile "digital economy", there has been relatively little interest in this amongst schools, teachers and politicians. Thus, any attempt at stimulating change would require significant resources and infrastructural investment.

Technocamps was created to take up this challenge, through a multi-faceted university-based operation engaging with schools, interacting with both pupils and their teachers throughout Wales and across all ages. Its main activities are as follows:

Workshops. One-day campus-based workshops offered to whole classes to give the pupils an introduction to computing, particularly computational thinking and real world problem solving. The whole class approach allows us: to address the gender divide, by engaging with an equal number of boys and girls; and to engage with those with no predisposition (or indeed a clear aversion) to digital technologies, creating an interest in computing and its application to the world [Ball et al. 2012].
Technoclubs[11]. Lunchtime clubs in schools where pupils develop their computational thinking and building skills.
Bootcamps. Two-day campus-based workshops held during school holidays.
After Schools Clubs. Two-hour late afternoon sessions held on campus or in the community. There are two types of such clubs: one standard computing club in which participants get lessons, tutoring and individual help on all manner of programming tasks, for example with Python, Visual Basic, XHTML/CSS, RobotC or an Arduino robotics project; and the other on computational thinking, called the Logic Club, in which the participants work on problem-solving tasks, typically developing step-by-step algorithmic solutions to a series of problems of varying difficulty.
Playground Computing[12]. Day-long school-based workshops which present the fundamentals of computer science to primary school pupils through playful activities which develop computational thinking and problem solving skills, but do not involve computers.
Technoteach[13]. Training sessions, typically in the form of 20-hour modules delivered one evening per week over six weeks. The Technoteach modules have been accredited by ASFI – Accredited Skills For Industry – for their Certificate in Computing for Teaching. Technoteach also encompasses other standalone twilight sessions as well as an annual teachers conference.
NEET Engagement. Week-long Summer residential sessions run in partnership with the municipal youth services in which young people identified as NEET ("Not in Employment, Education or Training") carry out a variety of team-building exercises, learn app development and compete to design and build the best app.
Student Placements. Computer Science students at the university are offered the opportunity to gain credits for their university degree programme through placements – one day per week – as teaching assistants in school computing/ICT classes.

A key factor in the success of Technocamps has been that all Technocamps activities are provided completely free of charge for all of its participants. While this represents a significant investment on the part of the university partners, Technocamps has also

[11] http://www.technocamps.com/technoclubs
[12] http://www.playgroundcomputing.com
[13] http://www.technocamps.com/technoteach

received various sources of funding in support of its activities; the main funders are as follows:

European Social Funds. (October 2010 - September 2014) – A four-year £6 million Welsh Government/EU-funded project to engage with secondary schools across South West Wales and the Valleys. This project involved Technocamps hubs at Aberystwyth University, Bangor University and University of Glamorgan (now the University of South Wales). Some 9,000 pupils from more than 180 schools and colleges have benefited from this project, as well as their teachers.
Nesta. (June 2013 - December 2014) – An 18-month £46,000 project to support the Playground Computing programme. This funding allows for a teacher to be seconded for 18 months to Technocamps in order to go out to primary schools throughout South Wales every day to present workshops. It has seen some 5,000 pupils at over 50 primary schools enjoy multiple day-long visits.
National Science Academy, Welsh Government. (November 2013 - March 2015) – A 17-month £24,000 project to support the Technoteach programme by the Welsh Government's NSA Grant Scheme; this funding was mainly in support of teachers registering on our six-week Technoteach modules, specifically providing their schools an amount of teacher cover to facilitate their attendance on the module. Over 120 teachers have thus far benefited from this project.
Learning in Digital Wales, Welsh Government. (September 2014 - March 2016) – An 18-month £370,000 project under the Welsh Government's Learning in Digital Wales (LiDW) Programme. The LiDW Tender is to deliver 3-hour taster sessions at each of the 210 state-sponsored secondary schools across Wales, and will be delivered by each of the six Technocamps hubs.
National Science Academy, Welsh Government. (April 2015 - March 2016) – A three-year £120,000 grant to support the Technoteach and Playground Computing programmes.

3.2. Measuring Impact: Wales Divided

In 2010, based on long-term empirical data regarding its effect on school children's attitudes towards computer science and technology careers – as well as their teachers' – Swansea University was awarded £3.9 million funding towards a £6 million four-year project (with the remaining £2.1 million generated through matched funding from the university) by the Welsh Government under the EU's European Social Fund (ESF) Convergence Programme to run Technocamps with regional hubs at the Universities of Aberystwyth, Bangor and South Wales. Due to EU restrictions, Technocamps was prohibited from providing any support (specifically, resources for workshops, teacher sessions, Technoclub support, etc) to schools outside of the Convergence area – namely, the eastern region of Wales, including its capital city Cardiff, bordering England. Whilst an unfortunate artefact of the funding, a fortuitous side effect of this restriction was that it allows for a true assessment of the real impact of Technocamps, as the nation was invariably divided into two halves: West Wales received the full Technocamps experience, whilst East Wales (including its capital, Cardiff) did not.

Due to its EU funding restrictions during 2011-2014, Technocamps was prohibited from providing any support (specifically, resources for workshops, teacher sessions, Technoclub support, etc) to schools outside of the Convergence area – namely, the eastern region of Wales, including its capital city Cardiff, bordering England (see Figure 1(a)). Whilst an unfortunate artefact of the funding, a fortuitous side effect of this restriction was that it allows for a true assessment of the real impact of Technocamps, as the country was invariably divided into two halves: West Wales and the Valleys

receiving the full Technocamps experience, whilst East Wales (including its capital, Cardiff) did not[14].

Cardiff is the primary base of Computing At School (CAS) in Wales; and since 2010 Technocamps has supported CAS in promoting their teacher-led initiatives (specifically the local/regional CAS Hub model and the CAS Network of Excellence [Brown et al. 2014; Sentance et al. 2014]). In particular, in 2010 Technocamps and CAS jointly sent out an information pack to every secondary school in Wales, following similar initiatives in England and Scotland. Technocamps produced the packs and posted these out to all of the schools; CAS Wales provided the costs for sending the information packs to the schools outside of the Convergence area of Wales (CAS Wales had a grant of c.£100,000 from Welsh Government to support the development of the CAS Network of Excellence model of teacher-led activity across Wales, supplementing the several millions of pounds granted to CAS by the UK Government for this activity across England). The information pack included full details of the extensive resources being supplied on the Technocamps and CAS websites, which schools and teachers could freely download and use, in particular in support of extra-curricular computing clubs.

Despite the non-recurrent financial support of CAS Wales, and the support it offers teachers in Wales, the CAS model – so successful in populous and geographically dense England – has never proven successful in Wales. For example, whilst CAS Hubs across the UK are generally run *by* schools *for* schools, abiding to the principle of the teacher-led initiative, virtually all of the CAS hubs across Wales are led by academics in university-based Technocamps Hubs (Dr Tom Crick at Cardiff Metropolitan University, Dr Helen Phillips at Cardiff University, Prof Andrew Ware at University of South Wales, Prof Vic Grout at Glyndŵr University, Prof Roger Boyle at Aberystwyth University, and Dr Dave Perkins at Bangor University). Teachers have generally not been as self-organising in Wales compared to England to directly promote the wider CAS agenda to support curriculum reform and building a teacher-led community.

In contrast to this, an independent review [Wavehill Ltd 2015] of Technocamps activity in the (socio-economically disadvantaged) Convergence region of Wales carried out for Welsh Government estimates that 5% of its secondary school-aged youths (ie, aged 11-19) have engaged with Technocamps through Workshops, and that more than a quarter of the secondary schools in the region have established Technoclubs. Furthermore, the new GCSE Computer Science qualifications – which has patchy uptake in Wales due to the lack of curriculum reform – has now been adopted by a large percentage of these schools, whilst schools outside of the Convergence area (and outside the reach of Technocamps) continue to deliver the ICT curriculum.

Although it could not operate within the non-Convergence area of Wales, Technocamps promoted all of its extensive on-line resources which are freely available to schools outside the Convergence area of Wales, and supported the activities of CAS Wales to develop the CAS Network of Excellence model of teacher-led school-based activities throughout Wales. However, despite the sustained efforts of CAS Wales, there are very few active and sustained school-based computing clubs that are not inside the Convergence area and established due directly to Technocamps workshops and follow-up engagement.

In support of this claim, consider the following example: the Annual Technocamps Robotics Competition has been open to all schools across Wales, promoted across all of Wales through Technocamps and CAS Wales networks, and even held on the outskirts of Cardiff in 2013. However, every single one of the 43 teams entered in the 2013 competition held near Cardiff travelled in from a Convergence area Technoclub formed

[14]In fact, the Convergence area encompasses closer to two-thirds of Wales, measured both in population and area.

on the back of Technocamps workshops and follow-up engagements with Technocamps initiatives. This provides clear evidence that the Technocamps model of intense direct engagement through campus-based workshops, in conjunction with teacher CPD and support, is crucial for success in promoting uptake of the discipline of computer science. The lack of confidence and isolation felt by the teacher community in Wales means that computing clubs have only arisen – and will likely only continue to develop – through direct involvement of and engagement with Technocamps.

3.3. Teacher Recognition

In Spring 2015, as part of the Welsh Government's *Learning in Digital Wales* programme, an anonymous on-line survey was carried out. A link to the survey[15] was sent out to head teachers and ICT/Computing subject head teachers in every Secondary School across Wales. The survey set out to measure the extent to which schools and teachers: understood the (need for) proposed changes to the computing curriculum; felt the need for support to face these changes; and recognised the various organisations and facilities that were providing such support.

Responses to the survey were submitted from over a third of such schools, and these depict Technocamps in a particularly positive light. In particular, only one respondent claimed to be unaware of Technocamps, whereas over 85% of respondents were not only aware of Technocamps but were actively benefitting from its various activities. In contrast, only 60% were aware of and benefitted from CAS, whilst 19% were unaware of CAS.

The lack of awareness and benefits of CAS is due, in no small part, to the Anglocentric nature of CAS. However, even flagship facilities created by the Welsh Government's Department of Education and promoted heavily within schools were not as well regarded: whilst every respondent was naturally aware of its online digital portal *Hwb*/*Hwb*+, only 57% benefit from it; and a full 24% unaware of their regional educational consortium with only 51% benefitting from it.

3.4. Government Impact

The impact described above that the various Technocamps initiatives have had on changing perceptions in schools has translated into impact on Welsh (and UK) Government thinking and policymaking within a number of different departments. We are able to cite a variety of data points which evidence this fact:

— In his keynote speech at the 2012 Annual Technocamps/CAS Teachers' Conference[16], the then Welsh Government's Minister for Education and Skills publicly acknowledged the importance of computer science education for all and how it addressed the key educational priorities in Wales, noting in particular the wide impact of Technocamps on pupils and schools; and expressed understanding of the wider educational and socio-economic impact that the government can make with educational reform in Wales. He also announced a variety of funded initiatives to support Technocamps' aims of embedding computing within the school curriculum at all levels.

> Computer science touches upon all three of my education priorities: literacy, numeracy and bridging the gap. It equips learners with the problem-solving skills so important in life and work.
>
> The value of computational thinking, problem-solving skills and information literacy is huge, across all subjects in the curriculum. I therefore

[15] http://goo.gl/forms/VdYSb6Up8q

[16] http://www.technocamps.com/blog/boost-digital-literacy-and-computer-science

believe that every child should have the opportunity to learn concepts and principles from computer science.

Indeed, computing is a high priority area for growth in Wales. The future supply and demand for science, technology and mathematics graduates is essential if Wales is to compete in the global economy.

It is therefore vitally important that every child in Wales has the opportunity to study computer science.

— One of the initiatives the Minister announced in his 2012 speech was the creation of a new government oversight panel – the National Digital Learning Council (NDLC)[17] – which would work on scoping the route forward for his department and ICT strategy more broadly; and in his speech he appointed the Director of Technocamps as an Expert Advisor to this panel.
— In 2013, the Minister commissioned an independent Review of the ICT Curriculum, citing the impact of Technocamps with its Director included amongst its members.
— The Director of Technocamps sits on the National Assembly for Wales Cross Party Group on Science and Technology.
— Technocamps has been recognised by the UK Government as the driving force for computing education in Wales, through an invitation to appear at the Houses of Parliament in October 2014, hosted by the Chair of the House of Commons Science and Technology Select Committee.
— The impact that Technocamps has had on schools in the Convergence area of Wales has been recognised by the Department for Education and Skills (DfES) which has contracted Technocamps to deliver workshops at every state-sponsored secondary school throughout the whole country between September 2014 and March 2016 as part of their *Learning in Digital Wales* programme.
— The impact that Technocamps has had on teachers has been recognised by the Department for Economy, Science and Transport (DEST), through the National Science Academy (NSA), which has contracted Technocamps to deliver its 20-hour Technoteach module between April 2015 and March 2018.
— The impact that Technocamps has had on primary schools has also been recognised by DEST, again through the NSA, which has contracted Technocamps to deliver its Playground Computing programme between April 2015 and March 2018.

4. EDUCATIONAL REFORM IN WALES

As noted above, in light of the perceived failings within education in Wales there have been a great number of reviews commissioned to identify failures and make recommendations to rectify these; we reflect on three recent reviews which are particularly pertinent.

4.1. 2013 ICT Curriculum Review

In Wales as elsewhere, there has been much focus on the use of technology in education. In September 2011, the Minister for Education and Skills commissioned a review of "digital classroom teaching", setting up an independent group to identify which digital classroom delivery aspects should be adopted to transform learning and teaching for those aged 3 to 19.

Alongside the commitment of significant funding for e-infrastructure to support learning and teaching in Wales, in September 2012 the Welsh Government established the National Digital Learning Council to provide expert and strategic guidance on the use of digital technology in teaching and learning in Wales. The remit of the Council was to guide the implementation of the *Learning in Digital Wales* programme

[17] https://hwb.wales.gov.uk/pages/Community-NDLC

(a strategic investment on next-generation connectivity for schools in Wales) and to promote and support the use of digital resources and technologies by learners and teachers. This policy focus on the use of technology in education stimulated focus on the academic disciplines of ICT and computer science in Wales, alongside significant scrutiny of the availability of qualifications [Royal Academy of Engineering 2012] in this space (as well as increasing divergence between the education systems in England and Wales, which share exit qualifications for 16 and 18 year olds: GCSEs and A-Levels).

In January 2013, the Welsh Government's Minister for Education and Skills announced the formation of an ICT Steering Group to consider the future of computer science and ICT in schools in Wales, framed by the outcomes of a Ministerial announcement and seminar in November 2012, attended by representatives from a range of key stakeholders including schools, the National Digital Learning Council, further education, higher education, awarding organisations, industry and the media. This was alongside significant focus on computer science education more broadly, as evidenced by the aforementioned Ministerial speech from 2012.

In January 2013, the Minister for Education and Skills announced the formation of an ICT Steering Group to consider the future of computer science and ICT in schools in Wales. Its remit was to explore the issues that ICT in schools needed to be re-branded, re-engineered and made relevant to now and to the future; computer science should be introduced at primary school and developed over the course of the curriculum so that learners can progress into a career pathway in the sector; skills, such as creative problem-solving, should be explicitly reflected in the curriculum; with revised qualifications to be developed in partnership with schools, higher education and industry. It was initially envisaged to report back in Autumn 2013, with its recommendations informing the wider review of assessment and 14-19 qualifications, with any necessary changes being considered as part of any revisions to the National Curriculum in Wales.

The key themes derived from the seminar, as well as wider policy developments, provided the following remit for the ICT Steering Group:

— ICT in schools needs to be re-branded, re-engineered and made relevant to now and to the future;
— Digital literacy is the start and not the end point – learners need to be taught to create as well as to consume;
— Computer science should be introduced at primary school and developed over the course of the curriculum so that learners can progress into a career pathway in the sector;
— Skills, such as creative problem-solving, should be reflected in the curriculum; and
— Revised qualifications need to be developed in partnership with schools, higher education and industry.

The membership of the ICT Steering Group was comprised of representatives from a cross-section of key stakeholders, tasked with providing clear recommendations on the way forward for computer science and ICT in Wales. It was initially envisaged to report back in Autumn 2013, with its recommendations informing the wider review of assessment and 14-19 qualifications [Welsh Government 2014b], with any necessary changes being considered as part of any revisions to the National Curriculum in Wales.

After eight months of discussion and evaluation, including an open consultation and a number of stakeholder events through the Summer of 2013, the ICT Steering Group published its recommendations [Arthur et al. 2013] for a way forward for ICT in Wales in October 2013, highlighting the importance of computing and digital literacy in a modern, challenging and aspirational national curriculum. Its headline recommenda-

tions were grouped into three main themes: curriculum and qualifications; teacher training and professional development; and infrastructure and monitoring.

The ICT Steering Group published its recommendations [Arthur et al. 2013] in October 2013, highlighting the importance of computing and digital literacy in a modern, challenging and aspirational national curriculum. Its headline recommendations were grouped into three main themes: curriculum and qualifications; teacher training and professional development; and infrastructure and monitoring. The report recommended that ICT be replaced from Foundation Phase onwards by a new subject named Computing. This subject would disaggregate into two main disciplines: Computer Science (CS) and Information Technology (IT); this new subject should be integrated into the curriculum as the fourth science, served by a mandatory programme of study, and receive the same status as the other three sciences. It recommended a clear distinction between cross-curricular digital literacies and the academic discipline of computing by proposing a statutory digital competency framework to work alongside existing frameworks for literacy and numeracy from Foundation Phase through to post-16 education. There was also a strong focus on supporting the ICT teaching profession in Wales, particularly around initial teacher education and incentivising routes into the profession, as well as raising the profile and importance of career-long professional development and in-service training.

(1) A new subject named Computing should be created to replace Information and Communications Technology (ICT) from Foundation Phase onwards. This new subject will disaggregate into two main areas: Computer Science (CS); and Information Technology (IT)
(2) Computing should be integrated into the curriculum as the fourth science, served by a mandatory Programme of Study, and receive the same status as the other three sciences.
(3) A Statutory Digital Literacy (DL) Framework should be implemented to work alongside the Literacy and Numeracy Framework from Foundation Phase through to post-16 education.
(4) Perceptions of Computing education pathways should be changed to recognise the key societal roles of computing and technology, as well as promote the importance and diversity of IT careers.
(5) The revised Computing curriculum should encourage creativity, allow thematic working and develop real world problem-solving. It should be flexible enough to continually evolve to remain current, adopting an Agile ideology and approach to ensure this.
(6) A range of engaging and academically rigorous pathways and bilingual qualifications for Computing and Digital Literacy should be devised, encouraging interest and opportunities for deeper learning.
(7) Engagement and collaboration between education and industry should be an integral part of the curriculum to embed current practices and skills.
(8) Pathways for Initial Teacher Training (ITT) in Computing should be created to encourage the best talent into the profession. All entrants to the teaching profession should have the skills to deliver the Digital Literacy Framework (DLF).
(9) A programme of training and professional development to enable the new Computing curriculum should be accessible to new and existing teachers.
(10) A National Technology Framework should be devised to create an effective technology infrastructure for education. Welsh Government, local authorities, industry and learning providers should be responsible for its effective implementation and strategic development.

(11) Effective monitoring arrangements should be created for Computing and the Digital Literacy Framework. Estyn should consider relevant changes to the Common Inspection Framework in light of all of these recommendations.
(12) An appropriate body or properly constituted group should oversee the implementation of these recommendations. Its remit would need to be broad enough to encompass this crucial governance role, utilising appropriate expertise and representing key stakeholders.

In the context of the recently announced new computing curriculum in England, the ICT Steering Group's report was well-received, addressing the specificity of the educational challenges in Wales, as well as providing a broad and balanced curriculum, from digital competencies through to computer science. However, as this was an independent review, the recommendations were non-binding and an official response from the Welsh Government was only received in March 2014 [Welsh Government 2014a]. In this period, there had been further developments in the wider review of the curriculum and assessment arrangements in Wales. While aspects of the recommendations around digital competencies have been accepted, everything relating to curriculum and qualifications was preempted by the announcement in March 2014 of a wholesale independent review to provide recommendations to inform the development of a new Curriculum for Wales. The report of the ICT Steering Group formed an important part of the evidence base for this review going forward.

4.2. 2015 Donaldson Review

In March 2014, Professor Graham Donaldson, a former chief school inspector in Scotland, was appointed by the Welsh Government to conduct an independent review of curriculum and assessment arrangements of the entire curriculum in Wales. This continued on from a number of previous national consultations and reviews, such as the 2011-2012 Review of Qualifications [Welsh Government 2014b] for 14 to 19-year-olds in Wales (which aimed to ensure that qualifications in Wales are understood and valued and meet the needs of young people and the Welsh economy), as well as aggregating a number of independent subject-specific reviews, for example arts, physical education and *Y Cwricwlwm Cymreig* (the Welsh cultural dimension of the curriculum), and the 2013 ICT review.

The Donaldson report (*"Successful Futures"*) [Donaldson 2015] published in February 2015, proposes profound changes to the education system in Wales. While identifying strengths in the current education system, for example the Foundation Phase and the commitment to the Welsh language and culture, the report identifies significant shortcomings of the current curriculum arrangements, which essentially remain as devised in 1988 (when it shared a national curriculum with England). The report argues that the curriculum has become overloaded, complicated and, in many parts, outdated. It identifies four purposes for the curriculum, recommending that the entirety of the school curriculum should be designed to help all children and young people to become: ambitious, capable learners, ready to learn throughout their lives; enterprising, creative contributors, ready to play a full part in life and work; ethical, informed citizens of Wales and the world; and healthy, confident individuals, ready to lead fulfilling lives as valued members of society. There are a number of similarities to the Scottish *Curriculum for Excellence* model[18], of which Donaldson was also involved.

With respect to computing education and the role of technology, the review identifies three cross-cutting, whole-schools "collective responsibilities": literacy, numeracy and digital competencies. With the structure of Foundation and Key Stages disappearing,

[18]http://www.educationscotland.gov.uk/learningandteaching/thecurriculum/

individual curriculum subjects would be replaced with six "areas of learning", in which subjects should "service the curriculum but not define it". All teaching and learning would be directed to achieving the four curriculum purposes.

The Donaldson review recognises and adopts many of the recommendations of the 2013 ICT review, recognising the importance of separating digital competencies from the curriculum subject of computing, but providing clear pathways as well as significant opportunities for cross-curricular learning across science and mathematics. Computer science would thus sit within a new Science & Technology area, with a clear strand of learning from aged five through to qualifications at 16 and 18. Furthermore, it recommends a programme of professional learning to be developed to ensure that the implications of the review for the skills and knowledge of teachers are fully met, although no timescale for delivery were proposed (due to the required legislative changes). This curriculum review was cautiously well-received by the education community and the media [BBC News 2015] in Wales, with significant detail remaining to be seen in implementation, resourcing and timescales.

4.3. 2015 Furlong Review and the New Deal

The publication of the Donaldson curriculum review was quickly followed by a review of initial teacher education in March 2015, led by Professor John Furlong. His review [Furlong 2015] notes that teacher training is at a "critical turning point" and needs to be changed, suffering as it does from a vacuum in the leadership in Wales, substantial under-investment, and support for staffing by universities in their education departments and faculties falling well short of best practice in other parts of the UK and internationally. While not specifically addressing issues for individual subjects, it notes the rise in expectations of the proposed curriculum from the Donaldson review (both in subject knowledge, as well as delivery), as well as explicitly referring to expectations of digital competencies in the qualified teacher standards, as well as how best to incentivise the best applicants to enter the teaching profession in Wales (as evidenced by the current situation for funding in Wales[19] vs. England[20]), again linking to the recommendations of the 2013 ICT review.

The Furlong review was announced alongside the Welsh Government's "New Deal" for the Education Workforce, complementing the outcomes from the previous reviews, to reshape continuing professional development for teaching professionals to support them in shaping and delivering the new curriculum. In this New Deal, career-long professional development is a priority, with plans to introduce a new Professional Learning Passport for teachers in Wales, as well as the Welsh Government supporting schools to produce tailor-made School Development Plans which will have workforce development at their centre, engaging all staff in high quality continuing professional development.

Digital Competence Framework. As one of the first post-Donaldson policy interventions, the Welsh Government announced in June 2015 that a new framework to support and develop digital competencies across the curriculum – to help pupils of all ages widen and develop their digital skills – will be available to schools by September 2016. The announcement explicitly acknowledged the central role that digital competence have to a young person's success in life. As per the 2013 ICT review, this framework is separate but complementary to the proposed new computing curriculum that would sit within the new *Science & Technology* area of learning, recognising the range and depth of dig-

[19]http://teachertrainingcymru.org/node/16

[20]https://getintoteaching.education.gov.uk/bursaries-and-funding and http://academy.bcs.org/content/eligibility

ital competencies (potentially including modelling, programming and computational thinking) to support all of the other curriculum subjects.

THIS NEEDS UPDATING: The Digital Competence Framework will be developed and implemented from September 2015 through partnership working between Welsh Government, leading schools in the field that will be awarded Digital Pioneer status, regional consortia and experts from higher education and industry, to enable schools to embed digital competencies into their teaching and learning to share their best practice across Wales.

5. THE FUTURE

As we have presented here and previously [**?**], Wales is at the cusp of implementing significant educational reform, with strategic importance given to digital competencies and computer science. The May 2016 devolved government elections have elected a new Welsh Government with refreshed ministerial portfolios to shape education and skills policy, as well as policy related to the digital economy for our prospective "agile digital nation". We may see a number of testbed initiatives and activities useful to other nations reforming their curricula, especially in the context of high-value digital competencies.

However, there remain significant challenges, particularly around wider public perceptions of the disciplines and its inherent educational and economic value, and how to upskill the entire teaching community of Wales. This is the profound and long-term challenge that has to be recognised and addressed before we see the type of computer science education that is fit for purpose and does not actively dissuade students from progressing onto degree-level study or opting for diverse careers in the technology profession.

As we have explained in the previous section, Wales is at the cusp of significant educational reform. In the context of UK-wide demand and both educational and economic imperatives for high-value digital skills (both to support a digitally-confident and capable citizenry, but also for creator skills to support high-tech innovation [UK Digital Skills Taskforce 2014; UK House of Lords Select Committee on Digital Skills 2015]), the challenges of a devolved education system to address the specific educational problems are many. With the publication of the 2015 Donaldson Report [Donaldson 2015], fully supporting the recommendations of the 2013 Review of the ICT Curriculum [Arthur et al. 2013], there now exists a framework in Wales for rethinking the role of digital competencies and computational skills in the education of all young people from early-years through to exit-level qualifications. Nevertheless, there are significant challenges remaining, even if there is some clarity around policy: in particular, around wider public perceptions of the disciplines and its inherent educational and economic value, but especially around up-skilling essentially the entire teaching community of Wales. This is the profound and long-term challenge that has to be recognised and addressed before we see the type of computer science education that is fit for purpose and does not actively dissuade students from progressing onto degree-level study or opting for careers in the technology profession.

Timescales for change are another key issue; as we have seen in the Scottish Curriculum for Excellence model – first proposed in a 2002 consultation exercise and then implemented in 2010-2011 – there is significant lag from inception through to implementation, particularly when legislative changes are required.

In England, even though there was already a critical mass of computing teachers mobilised by the CAS initiative, there was still a profound and disruptive shift in attitude felt in the teaching community once the Government formally announced the new Computing curriculum would be introduced from September 2014. this critical mass does not currently exist in Wales, and it is even more critical for the Welsh Gov-

ernment to influence the teaching community through its public pronouncements and policy interventions over the coming 12-18 months. We note that the challenges facing Wales – as a small aspiring digital nation facing substantive curriculum reform – are not necessarily unique; it would be interesting to compare and contrast with more mature initiatives in, for example, Israel [Armonia and Gal-Ezerb 2014].

In England, despite the presence of a critical mass of computing teachers mobilised by the successful CAS initiative, there was still a profound and disruptive shift in attitude felt in the teaching community once the UK Government formally announced the new Computing curriculum would be introduced from September 2014. This momentum does not currently exist in Wales, and it is even more critical for the Welsh Government to influence the teaching community through its policy interventions. Furthermore, any new initiatives in this space have to address local/regional needs, but with strategic coordination at the national level; the previous funding model of Technocamps has clearly had an impact on engagement, upskilling and the wider perception change in the non-Convergence area of Wales.

Technocamps has been working through its Technoteach programme to create a small but critical mass of ready computing teachers, necessarily through a programme of direct and intense intervention. Public pronouncements from Welsh Government regarding its intentions to follow England in fully adopting computing education in schools will be needed to secure the schools' buy-in to ICT teacher CPD in readiness for the new curriculum. The Technoteach model of direct intervention will clearly remain necessary for some time after such government declarations; but in the fullness of time, and with a growing community of confident teachers, we will eventually arrive at a situation in which the teacher-led CAS model will be as effective in Wales as it has been in England.

Technocamps has been working through its Technoteach programme to create a small but critical mass of qualified teachers, necessarily through a programme of direct and intense intervention. Public pronouncements from Welsh Government regarding its intentions to follow England in fully adopting computer science education in schools will be needed to secure the schools' buy-in to teacher CPD in readiness for the new curriculum. The Technoteach model of direct intervention will clearly remain necessary for some time after such government declarations; but in the fullness of time, and with a growing community of confident teachers, we will eventually arrive at a situation in which the teacher-led CAS model will be as effective in Wales as it has been in England. Furthermore, this hybrid practitioner model of "pioneers" and master teachers cascading best practice may be of relevance to other disciplines (such as mathematics and the sciences), as well as other nations reforming their computing and technology curricula.

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