# A National Engagement Model for Developing Computer Science Education in Wales

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**Abstract** Computer science education in the United Kingdom has undergone substantial scrutiny, and in England a new computing curriculum has just been introduced. However, in Wales – a devolved nation within the UK – political, geographical and socio-technical issues have hindered any substantive educational policy or curriculum reform for computer science over the past ten years. In this paper we present the activities of Technocamps, a university-based schools outreach programme founded in 2003 and its wider impact on computer science education and teachers in Wales. Furthermore, with imminent curriculum reform, we frame the wider opportunity for sustainably embedding both high-value digital competencies and computer science education – as well as changing the wider public perception and importance of computer science – as a prospective replicable case study of a national engagement model for countries with similar aspirations of becoming digitally confident and capable nations.

## 1 Introduction

In the 1980s, computer studies was a popular subject in schools across the UK. The ubiquitous presence of the popular BBC Micro[3] – 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.

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

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

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 [1].

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 [2–6]. Younie [7] 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 [8], while generally viewed to be more flexible and less prescriptive than the equivalent subject in England, exhibited many of the same issues [9, 10]. 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 [11]. The situation is worse in Wales, where this figure rises to 75% [12], 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 [13], the UK's innovation charity and one by the Royal Society [11], 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 [14]. The 2011 Wolf review [15] 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 associated 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 [16, 17].

Technocamps[4], 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 [18]; 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.

## 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) [19]. 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 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 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 [20], Sweden [21] and Israel [22]). 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 portfolio transferred to the National Assembly of Wales, it has suffered a rapid decline. Evans [23] presents a detailed analysis as to the cause

[4] http://www.technocamps.com

of this, citing a multitude of policy changes and poor interventions, alongside a hard-hitting report from the OECD [24].

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[5], 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 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 reviews before his resignation in February 2013 – almost one per month [23].

With devolved government comes fiscal autonomy; 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.

When establishing a model for viewing school computer science education, it is apparent that there is substantial diversity between school education systems [25], and this can create obstacles when trying to understand progress made in one country and potentially replicate it in another [26]; this is also pertinent to the devolved (and diverging) educational systems of the UK.

## 3 The Technocamps Initiative

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 overburdened and disinterested in exploring any perceptions of inadequacy in the curriculum and their delivery [16, 17].

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 reintroduce computer science into the ICT curriculum by generating the demand

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

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 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 – 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, as well as the teaching community in Wales. The wide spectrum of Technocamps activities is presented in further detail in [18]; here we assess its wider impact.

### 3.1 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.

Cardiff is the primary base of Computing At School (CAS) in Wales; CAS have been widely recognised for their role in reform of the Computing curriculum in England [27]. 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 [14,27,28]). 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 (in 2012, CAS Wales was awarded a grant of c.£70,000 from the 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 [28] – 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 university academics who also run Technocamps Hubs. Teachers have generally not been as self-organising in Wales compared to England to promote the wider CAS agenda to support curriculum reform and building a teacher-led community.

In contrast to this, an independent review [29] 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 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 and A-Level Computer Science qualifications (taken at 16 and 18 respectively) – which has had patchy uptake in Wales due to the lack of curriculum reform – are now starting to be adopted by an increasing 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 further 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 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.

### 3.2 Teacher Impact

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 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 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 Anglo-centric 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*[6], only 57% benefit from it; and a full 24% unaware of their regional educational consortium with only 51% benefitting from it.

### 3.3 Government Impact

The impact described above that the various Technocamps initiatives have had on changing perceptions in schools (both pupils and teachers) has also translated into impact on Welsh (and UK) Government thinking and policymaking. For example:

- In his speech at the 2012 Annual Technocamps Teachers' Conference[7], the Welsh Government's Minister for Education and Skills 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.
- One of the initiatives the Minister announced in his speech was the creation of a government oversight panel – the National Digital Learning Council (NDLC)[8] – which would work on scoping the way forward for his department's ICT strategy; and in his speech he appointed the Technocamps Director as an Expert Adviser to this panel.

[6] http://hwb.wales.gov.uk/

[7] http://gov.wales/newsroom/educationandskills/2012/120621digitaltechnology/?lang=en

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

- In 2013, the Minister commissioned an independent Review of the ICT Curriculum, citing the impact of Technocamps with its Director included amongst its members.
- 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.
- Technocamps' impact 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.
- Technocamps' impacts 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 teacher training between April 2015 and March 2018.
- Technocamps' impact on primary schools has also been recognised by DEST, through the NSA, which has contracted Technocamps to deliver its Playground Computing programme between April 2015 and March 2018.
- In the run up to the May 2016 Welsh Assembly (devolved government) elections, Technocamps was cited as the cornerstone of developing digital skills in Wales in the UK national press[9], heralding the importance of these skills for the economic future of the nation.

## 4 Education Policy Change in Wales

In light of the perceived failings within education in Wales there have been a number of reviews commissioned over the past five years to identify failures and make recommendations to rectify these; we reflect on two recent major reviews which are particularly pertinent to computing education.

**ICT Curriculum Review (2013):** 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

[9] e.g. http://www.huffingtonpost.co.uk/carwyn-jones/skills-for-the-jobs-of-today-and-tomorrow_b_9767130.html

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 ICT Steering Group published its recommendations [30] 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.

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. While aspects of the recommendations around digital competencies had been accepted, everything relating to curriculum and qualifications was preempted by the announcement in March 2014 of a independent review to provide recommendations to inform the development of a new Curriculum for Wales.

**Independent Curriculum for Wales Review (2015):** 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 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 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, including the 2013 ICT review.

The Donaldson report (*"Successful Futures"*) [31], was published in March 2015 and proposed profound changes to the education system in Wales. While identifying strengths in the current education system, for example the early years 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 Scotland's *Curriculum for Excellence*, 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, individual curriculum subjects would be replaced with six "areas of learning and experience", 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 in Wales, with significant detail remaining to be seen in implementation, resourcing and timescales. The publication of the Donaldson curriculum review was quickly followed by a review of initial teacher education in March 2015, 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 going forward into 2016.

## 5 Conclusions

As we have presented here and previously [18], 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.

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 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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