Technocamps: Advancing Computer Science Education in Wales

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ABSTRACT

Computer science education in the UK has undergone substantial scrutiny over the past five years. In particular, from September 2014, we have seen the implementation and delivery of a new computing curriculum in England. However, in Wales – one of the four devolved nation in the UK – numerous political, geographical and socio-technical issues have hindered any substantive educational policy or curriculum reform for computer science. This is despite the widespread efforts to address the failings of computer science education in schools since at least 2003 through Technocamps, a pan-Wales university-based schools outreach programme.

In this paper we outline the history (and pre-history) of Technocamps, contextualised by the devolved nature of education in the UK, positioning Wales with its specific issues and challenges. Furthermore, we present evidence both in support of this university engagement and intervention model as well as its wider positive effect on promoting and supporting computer science education in Wales, a nation about to take its first steps on the path of a large-scale national curriculum review and significant educational reform.

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 [28]. 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.

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 moved into the role of ICT teacher simply by being sufficiently digitally literate [23]. The situation is worse in Wales, where this figure rises to 75% [15], 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.

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[1] 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.

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[2] to run Technocamps as a pan-Wales project with regional hubs at the Universities of Aberystwyth, Bangor and Glamor-

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

[2] http://wefo.wales.gov.uk/programmes/20072013/convergence/?lang=en

gan (now University of South Wales).[3] 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)[4] 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 initiatives[5] – 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.

In this paper, we sketch the historical development of computing education in the UK (Section 2) and describe the backdrop to Technocamps and why it was created in the way it was, presenting data both in support of university intervention as well as the positive effect this intervention is having (Section 3). We finish with a consideration of the challenges remaining in computer science education in Wales (Section 4).

[3]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.

[4]http://www.computingatschool.org.uk

[5]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

2. COMPUTING EDUCATION IN THE UK

In the 1980s, computer studies was a popular subject in schools across the UK. The ubiquitous presence, in both schools and homes, of the popular BBC Micro – which was useful for little else 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 [11].

By the 1990s, however, the emergence of pre-installed software packages – 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 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 enquiries in 1997: the McKinsey Report [18] and the Stevenson Report [25]. 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 £3.5 billion in ICT in schools through various initiatives such as the National Grid for Learning (NGfL) and the New Opportunities Fund (NOF) [10].

By 2000, then, ICT had permeated both primary and secondary school curricula, not least in the newly-devolved nations. 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 [22, 19, 20, 21, 17]. Younie [32] summarises the problems identified by these reports into five key areas, three being management and the other two being: teacher training and competence; and impact on pedagogy. The ICT curriculum in Wales [29], while generally viewed to be more flexible and less prescriptive than the equivalent subject in England, exhibited many of the same issues [12, 13, 14].

A decade later, two reports – one from the Royal Society [23], the UK's premier science academy, alongside an influential industry report from Nesta [16], the UK's innovation charity – made the very same observations. The reports 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 find ICT in secondary school neither stimulating nor engaging. The Wolf Report [31] further notes that the undemanding nature of ICT qualifications in secondary schools is readily exploited by schools: due to a high 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

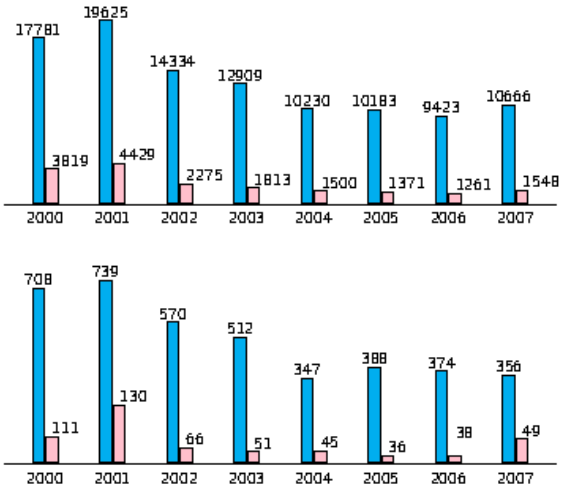

Figure 1: Applications to University computer science degree programmes in the UK (top) and Wales (bottom), males (blue) and females (pink). (source: Universities and Colleges Admissions Service (UCAS))

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 wrongly but innocently led to believe is computer science [8]. See [5, 6] for an in-depth discussion of the recent context of computing education in the UK.

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 1, 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 [6]).

In an attempt to address this worrying anomaly, the Department of Computer Science at Swansea University[6] 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 characterised 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 [8, 4, 6].

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 [30, 7] 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 [24] – 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.

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 [3].

Technoclubs[7] Lunchtime clubs in schools where pupils develop their computational thinking and building skills.

Bootcamps Two-day campus-based workshops held during school holidays.

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

[7]http://www.technocamps.com/technoclubs

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[8] 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[9] 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 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.

[8]http://www.playgroundcomputing.com

[9]http://www.technocamps.com/technoteach

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 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[10] 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 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/Hwb+*, only 57% benefit from it; and a full 24% unaware of their regional educational consortium with only 51% benefitting from it.

3.3 Government Recognition

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:

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

- In his keynote speech at the 2012 Annual Technocamps/CAS Teachers' Conference[11], 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.

- 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)[12] – 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.

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

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

4. THE FUTURE

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 [26, 27]), the challenges of a devolved education system to address the specific educational problems are many. With the publication of the 2015 Donaldson Report [9], fully supporting the recommendations of the 2013 Review of the ICT Curriculum [2], 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 Government 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 [1].

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.

5. REFERENCES

[1] M. Armonia and J. Gal-Ezerb. High school computer science education paves the way for higher education:

the Israeli case. *Computer Science Education*, 24(2-3), 2014.

[2] S. Arthur, T. Crick, and J. Hayward. The ICT Steering Group's Report to the Welsh Government. http://learning.wales.gov.uk/docs/learningwales/publications/131003-ict-steering-group-report-en.pdf, September 2013.

[3] C. Ball, F. Moller, and R. Pau. The mindstorm effect: a gender analysis on the influence of LEGO mindstorms in computer science education. In *Proceedings of the 7th Workshop in Primary and Secondary Computing Education (WiPSCE 2012)*, pages 141–142. ACM Press, 2012.

[4] R. D. Boyle, H. M. Dee, and F. Labrosse. Technocamps: bringing computer science to the far west. In *Proceedings of the 7th Workshop in Primary and Secondary Computing Education (WiPSCE 2012)*, pages 147–148. ACM Press, 2012.

[5] N. Brown, M. Kölling, T. Crick, S. Peyton Jones, S. Humphreys, and S. Sentance. Bringing Computer Science Back Into Schools: Lessons from the UK. In *Proceedings of the 44th ACM Technical Symposium on Computer Science Education (SIGCSE 2013)*, pages 269–274. ACM Press, 2013.

[6] N. Brown, S. Sentance, T. Crick, and S. Humphreys. Restart: The Resurgence of Computer Science in UK Schools. *ACM Transactions on Computer Science Education*, 14(2):1–22, 2014.

[7] A. Calderon, T. Crick, and C. Tryfona. Developing Computational Thinking through Pattern Recognition in Early Years Education. In *Proceedings of 29th BCS Conference on Human Computer Interaction (HCI 2015)*, 2015.

[8] T. Crick and S. Sentance. Computing At School: Stimulating Computing Education in the UK. In *Proceedings of the 11th Koli Calling International Conference on Computing Education Research*. ACM Press, 2012.

[9] G. Donaldson. Successful Futures: Independent Review of Curriculum and Assessment Arrangements in Wales. http://gov.wales/docs/dcells/publications/150317-successful-futures-en.pdf, February 2015.

[10] R. Doughty. The state of ICT in schools: The story so far. *Education Guardian*, pages 1–7, 4 April 2006.

[11] S. Doyle. *GCSE Computer Studies for You.* Hutchinson Education, 1988.

[12] Estyn. An evaluation of the impact of the Better Schools Fund provision for ICT in Schools. Technical report, Estyn, March 2007.

[13] Estyn. The impact of ICT on pupils' learning in primary schools. Technical report, Estyn, July 2013.

[14] Estyn. ICT at key stage 3: The impact of ICT on pupils' learning at key stage 3 in secondary schools. Technical report, Estyn, July 2014.

[15] General Teaching Council of Wales. Annual Statistics. http://www.gtcw.org.uk, March 2008.

[16] I. Livingstone and A. Hope. *Next Gen.* http://www.nesta.org.uk/publications/next-gen, 2011. Nesta.

[17] A. Loveless. Challenge and change with information technology in education: Do we really mean it? *Technology, Pedagogy and Education*, 13(3):277–281, 2005.

[18] McKinsey & Co. The future of Information Technology in UK schools: An independent inquiry. Technical report, 1997.

[19] Ofsted. ICT in schools: The impact of government initiatives; an interim report. Technical Report HMI 264, Office for Standards in Education (Ofsted), April 2001.

[20] Ofsted. ICT in schools: Effect of government initiatives; progress report. Technical Report HMI 423, Office for Standards in Education (Ofsted), April 2002.

[21] Ofsted. ICT in schools: The impact of government initiatives five years on. Technical Report HMI 2050, Office for Standards in Education (Ofsted), May 2004.

[22] C. Opie and K. Fukuyo. A tale of two national curriculums: Issues in implementing the national curriculum for information and communications technology in initial teacher training. *Technology, Pedagogy and Education*, 9(1):79–95, 2000.

[23] Royal Society. Shutdown or restart? The way forward for computing in UK schools. https://royalsociety.org/~/media/education/computing-in-schools/2012-01-12-computing-in-schools.pdf, January 2012.

[24] S. Sentance, M. Dorling, A. McNicol, and T. Crick. Grand Challenges for the UK: Upskilling Teachers to Teach Computer Science Within the Secondary Curriculum. In *Proceedings of the 7th Workshop in Primary and Secondary Computing Education (WiPSCE 2012)*, pages 82–85. ACM Press, 2012.

[25] D. Stevenson. Information and Communication Technology in UK schools: An independent inquiry. Technical report, The Independent ICT in Schools Commission, 1997.

[26] UK Digital Skills Taskforce. Digital Skills for Tomorrow's World, July 2014.

[27] UK House of Lords Select Committee on Digital Skills. Make or Break: The UK's Digital Future, February 2015.

[28] T. Vasko and D. Dicheva. Educational policies: an international review. Technical report, International Institute for Applied Systems Analysis, Luxenburg, Austria, September 1986.

[29] Welsh Government. Information and communication technology in the national curriculum for Wales. http://learning.gov.wales/resources/browse-all/ict-in-the-national-curriculum-for-wales/?lang=en, 2008.

[30] J. M. Wing. Computational Thinking and Thinking About Computing. *Philosophical Transactions of the Royal Society A*, 366(1881):3717–3725, 2008.

[31] A. Wolf. Review of vocational education: The Wolf report. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/180504/DFE-00031-2011.pdf, March 2011.

[32] S. Younie. Implementing government policy on ICT in education: Lessons learnt. *Education and Information Technologies*, 11:385–400, 2006.