

The Institute of Coding: A University-Industry Collaboration to Address the UK's Digital Skills Crisis

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ABSTRACT

The Institute of Coding is a new £40m+ initiative by the UK Government to “transform the digital skills profile of the country”. In the context of significant national and international policy scrutiny, it responds to the apparently contradictory data that the country has a digital skills shortage across a variety of sectors, yet the higher education system produced computing graduates every year who end up unemployed, or underemployed.

The Institute is a large-scale national intervention to address some of the perceived issues with formal education versus industry-focused skills and training, for example: technical skills versus soft skills, industry-readiness versus “deep education”, and managing expectations for the diverse digital, data and computational skills demands of employers across a wide range of economic sectors.

All of this is taking place at the higher education/industry interface at the same time as substantial computer science curriculum reform across the four nations of the UK – especially in England, with a new computing curriculum from 2014, in which all children are expected to learn two programming languages, as well as wider computer science fundamentals and develop transferable computational thinking skills.

In this paper, we describe the background, evidence base and rationale for the Institute of Coding, its key themes and current activities, as well as anticipate its likely impact over the coming years. Furthermore, we reflect on the potential replicability of aspects of the Institute (and related initiatives in the UK) to other nations or regions with similar ambitions to address the “digital skills crisis”.

CCS CONCEPTS

• **Social and professional topics** → **Computer science education; Information technology education; Software engineering education; Employment issues; Computing industry;**

KEYWORDS

Digital skills, Programming, Computer science education, Undergraduate education, Graduate education, Industry collaboration, UK

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1 INTRODUCTION

We are frequently being told that this is “the digital age”, and that we “live in a knowledge economy”¹, with “software eating the world” [1]; nevertheless, the impact of digital on all of our lives is clear. From entertainment and communication, via the power and reach of an oligopoly of social media platforms, with “algorithms” influencing what news we consume, or making decisions that affect us every day; to education, health and social care, through to innovation in public services [25]. We are also seeing the emergence of artificial intelligence and machine learning as general-purpose technologies that could transform whole industries and even reinvent the process of invention itself [7]. What does this mean for education systems, curricula and skills training – from compulsory, through to post-compulsory, into lifelong learning?

1.1 Defining the “Digital Economy”

Providing a comprehensive definition of the ‘digital economy’ is challenging; the OECD’s 2002 definition of the ICT sector does not provide much insight: “...a combination of manufacturing and services industries that capture, transmit and display data and information electronically” [37]. According to the current (but published in 2007!) UK Standard Industrial Classification of Economic Activities [39], the “Information and Communication” sector includes telecommunications, computer programming, information services, as well as a wide range of creative, publishing and broadcasting activities. Formal sector classifications aside, it is clear that while the UK may have a traditional vertical ‘IT and Telecoms’ sector, it also has a crucial enabling and facilitative horizontal digital sector – in essence: there is no such thing as the ‘digital economy’ – our economy is digital. While this situation is certainly not unique to the UK, it is perhaps exemplified by some of the grand challenges identified as part of the 2017 UK Industrial Strategy [16]: from precision medicine, manufacturing and future materials, to creative industries clusters and next generation services, through to driverless cars and smart cities [49].

In 2017, the UK digital sector comprised of 1.5 million jobs (4.6% of the total number of jobs in the UK), the highest number for the sector (and a 16.1% increase) since 2011 [20]. Its workers are more productive, on average, by £10,000 per worker and jobs requiring digital tech skills command higher salaries, at £42,578 compared to £32,477 for those that do not. Despite the stereotype that digital tech jobs are for “millennials”, 72% of workers are aged over 35; however, only 19% of the UK digital tech workforce is female [48]. Indeed, the Institute of Coding announcement [23] quoted the even more

¹Despite the debunking in [26].

pessimistic “In 2017, female programmers and software developers made up just 3.9 per cent of tech and telco professionals in the UK”.

1.2 Education and Skills Policy

Across the world there are a plethora of initiatives and interventions to address the wider societal challenge, and the corresponding skills shortages [10]. While there is a strong socio-economic policy focus, it should not just be about jobs: we want, and need, a digitally competent, capable and engaged citizenry. But this widespread ambition provides challenges for long-term, coherent policymaking: what do we mean by digital skills? In recent years, we have seen a multitude of policy reviews and reports from across government, academia, think tanks, learned societies and charities that have attempted to encapsulate some of the issues, as well as identifying potential solutions. At least three recent UK Parliament Select Committee inquiries [30–32] have, wholly or in part, focused on the ‘digital skills crisis’. They have all made a number of specific recommendations, from curriculum and qualifications reform, improving professional learning for practitioners, investment in infrastructure, developing effective pedagogies and the wider educational research base in the UK, through to terminology, fixing ‘leaky pipelines’ and changing the wider public perceptions of digital/technology disciplines.

Alongside substantial curriculum reform across the UK [5, 6, 13], including a new national curriculum in England [21] and emerging reform in Wales [2, 12, 35], we have also seen significant changes to the available qualifications, based on perceived rigour, content, distinctiveness and modes of assessment. The publication last year of a follow-up report on computing education in the UK from the Royal Society [40] framed some of these national challenges in the context of computing for all, calling for a coherent strategy so that all learners are equipped and empowered with the necessary skills to be effective in the digital world.

However, it is clear that from all of these various reviews, reports, activities, initiatives and interventions, there remains a lack of policy coherency and connectedness – more so when it cuts across ministerial portfolios, or requires multi-year coordinated support. In this paper we frame some of these strategic challenges – and opportunities – and introduce the Institute of Coding, a new £40m+ initiative by the UK Government (but focused on England, with related activity in Wales) to transform the digital skills profile of the country [14].

The structure of the paper is as follows. In Section 2 we attempt to define the wider problem through the lens of graduate employment and earnings; this is followed in Section 3 by the UK higher education policy context and the skills mismatch respectively; in Section 4 we present the Institute of Coding and its key themes and activities, finishing with future work and the potential replicability of aspects of the Institute in Section 6.

1.3 A Note on Nomenclature

While in many instances throughout this paper we will refer to the United Kingdom (UK) – consisting of the four nations of England, Scotland, Wales and Northern Ireland – many of the initiatives, approaches and funding models are specifically focused on England (or England and Wales), as a number of policy areas, including education and skills, are devolved to the respective governments.

We will attempt to be as clear as possible when referring to specific interventions across or between the four nations.

2 SO WHAT’S THE PROBLEM?

Superficially, the employment outlook for computing graduates in the UK looks excellent. A 2015 report from the UK Commission for Employment and Skills [50, p. 74] states:

...“the digital sub-sector will need 518,000 workers for roles in the three highest skilled occupational groups. However, over the last ten years only 164,000 individuals graduated from a first degree in computer science.”

This is beneficial to the individual: according to a 2011 UK Government report on economic returns from higher education qualifications [18, Figure 4], “mathematical and computer sciences” have the second highest earnings return of all subjects (overtaken only by “medicine and dentistry”). The country profits from this as well: per head, it is the fourth most beneficial subject to the UK [18, p. 16]. Nevertheless, despite the headline success in a variety of UK Government reports, the employment figures are not great, and the earnings data are patchy.

2.1 Graduate Employment

Further to the 2015 UK education and skills report [50], Sir Nigel Shadbolt highlighted the following in his 2016 UK Government review of computer sciences degree accreditation and graduate employability [47]:

“In this context, apparently high rates of unemployment² amongst graduates of Computer Sciences and other STEM³ courses demanded an explanation.

A significant explanation is “There are notable differences in the characteristics of Computer Sciences entrants compared to entrants in other STEM subjects” [47, ¶2.6]: fewer women, but:

50% more mature students;

16% more Black and Minority Ethnic (BME); and

40% more students from backgrounds where people have traditionally not participated in HE (low participation neighbourhoods, LPNs).

UK Government data suggests that Mature, BME and LPN students all find getting jobs more difficult. However, for those students that do find jobs, the data are better, showing [47, Figure 6] fewer students in “non-graduate jobs” or low-earning jobs than in STEM as a whole.

2.2 Graduate Earnings

If we look beyond purely getting jobs to the earnings⁴, the position (as described in official government figures [24], and analysed by the national media [3], which also allows the reader to break down the data by university and subject.) is even less clear on a microscopic

²11.7% six months after graduation (the standard UK measure) at the time of [47], compared with a STEM average of 8.4%. Note, however, that Computing is 20% of STEM [46, Table 1], so ‘STEM-less-Computing’ has a 7.6% unemployment rate.

³STEM is “Science, Technology, Engineering, Mathematics” for [47] and this paper.

⁴Clearly not the only measure of job quality, or contribution to society, but at least it is measurable, and has been measured in the UK graduate longitudinal education outcomes (LEO) dataset [22], which tracks individuals through school, university and into the labour market, combining educational, tax and benefits data.

level, though on a macroscopic level it supports the 2016 Shadbolt review findings [47].

On the macroscopic level, the reader should consider [24, Table 5]. We focus on the ‘Men’ data as presented here, as there are (regrettably) many more than there are women in the cohorts, though the effects are similar. An OLS (“Ordinary Least Squares”) fit shows that a man reading Computing would earn 3.3% more than had he read a subject at random. If one corrects for prior attainment, this rises to 10.5%, and 12.6% if other factors are taken into account. For reasons explained in [24, §4.2], the authors prefer IPRWA (“Inverse Probability Weighted Regression Adjustment”), and this moves the earning difference to 14.4%. For men, the overall effect of these adjustments is to move Computing from being middle-of-the-pack [24, Figure 15] to fourth best [24, Figure 17], and for women it moves to seventh best [24, Figure 16]. Note that these are improvements on the average graduate earnings which are £30,000/year for men and £26,000/year for women [24, p. 37]. Hence if a particular subject were sending students into a gender-neutral world, the women would be showing a 15% (£4,000/year) premium just to catch up with the men. It could be argued that maternity leave and other factors means that this is unrealistic, but the difference is due to much more than just that: [27, Figure 14] shows that for men the mean annual starting salary in Computing is £25,500, versus £24,000 for women.

2.3 Per-University Earnings

The 2018 BBC article [3] allows us to break down the data underpinning the official government figures [24], and the Computing figures are challenging. Salary premiums, allowing for the factors described above, are reported separately for men and women, and only if there were at least 50 students of that gender in the five cohorts (graduation 2007–8 to graduation 2011–12) considered. This means that, of the 82 English universities reporting computing, 80 report male data and 30 report female data – 28 report both. Looking at the 28 (see Figure 1), one’s first impression is that the male and female data are uncorrelated: for example the two universities with male premiums just above +£2500 have female premiums of +£9325 and -£5793. There is in fact a definite ($p = 0.0034$) positive correlation, but a fairly weak one ($R^2 = 0.286$). The best fit is $W = 0.92672 + 0.53388 * M$. For the reasons explained at the end of the previous section, the ideal “gender-neutral” fit would be $W = 4 + M$. Both these lines are presented in Figure 1.

2.4 Skills Mismatch

There is a widespread and longstanding complaint that “students aren’t industry-ready”, or “there is a skills mismatch”. Some of this is due to a misapprehension on the part of employers – and perhaps misunderstanding of the nature of education versus training (for example, exhibited by those outside the IT industry itself, but seeking to hire people with “10 years experience of programming in Ruby”), but much of it is genuine. Previous work in this space has focused on the evidence based for how programming and software engineering is taught at degree level [15, 36, 45]. One of the main challenges for the university community is to better understand this complaint.

3 UK HIGHER EDUCATION POLICY CONTEXT

After the UK Government’s acceptance of a 2010 review into higher education funding and student finance [17], students in England pay probably the highest⁵ prices in the world for undergraduate education: between £6000 and £9000/year for tuition alone. While this is normally covered by student loans repaid on an income-contingent basis, essentially through a 9% income tax premium, there is evidence [8] that this “contribute[s] to lower rates of planned H[igher] E[ducation] participation by lower-class students”.

3.1 Teaching Excellence Framework

UK universities have been judged, very publicly, on their research for the last thirty years by a large-scale national Research Assessment Exercise (RAE), and its successor the Research Evaluation Framework (REF). This has led to many complaints, largely justified, that teaching, because it is not measured, is not taken as seriously as research, certainly in some of the research-intensive universities. Similar comments in the USA can be found in [9]. To counteract this, the Government introduced (first grades published in June 2017) a “Teaching Excellence Framework” (TEF)⁶. The ostensible aim of the TEF was to evaluate the quality of provision for each higher education provider within the UK. The initial version of the TEF produced a university-wide assessment on a three-point (Gold-26%/Silver-50%/Bronze-24%) scale. It in fact used no direct assessment of teaching as such, primarily being based on historical statistical data.

In 2018, following an Institutional-level review undertaken in the previous year, the Office for Students (OFS) conducted a pilot of a national subject-based TEF. The objective was to provide sufficient data for prospective students to enable them to undertake an informed decision about their choice of University and subject of study. This was particularly pertinent to the UK context as the funding of higher education has shifted, following several policy changes [17], from students receiving means-tested Government grants to undertaking a loan to pay for their tuition.

The TEF’s reliance on employment metrics pre-supposes a strong correlation between the quality of provision and the employment prospects/performance of the students. This can be challenging for some disciplines (e.g. income earning potential is not equally distributed across all subjects). The intention however is clear. In the context of students paying their own tuition fees, quality of provision is being linked to future employment prospects. This represents an opportunity for HE Computing provision. Those programmes, characteristic of most in computer science, that contain a placement/internship, are professionally-accredited and whose curriculum is informed by an employer-led advisory board are well-placed to do well in the TEF.

3.2 Degree Apprenticeships

The Government has also launched “Degree Apprenticeships” [19]. These were described by the then Prime Minister as “combining

⁵Or possibly second-highest after US students, but the US averages in [38, Table B5.1] conceal an enormous variation.

⁶Now renamed “Teaching Excellence and Student Outcomes Framework”, which is somewhat more descriptive.

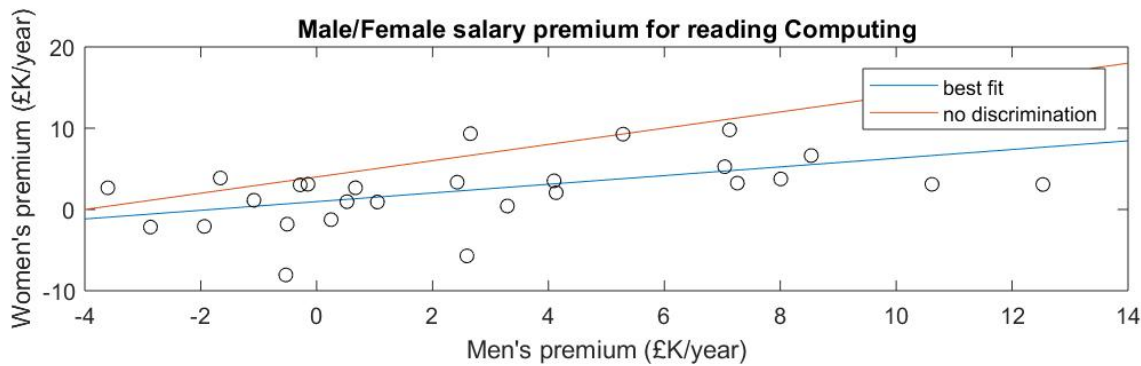


Figure 1

a full degree with the real practical skills gained in work and the financial security of a regular pay packet". The employer pays the tuition cost, but due to a national Apprenticeship Levy [29], essentially a 0.5% payroll tax, large (payroll over £3m) employers will find there is no net cost, while smaller employers can claim 90% of the cost back from the Government.

Degree Apprenticeships can be either "Level 6" (undergraduate/BSc level) or "Level 7" (postgraduate/MSc level). The Level 6 ones last 3–5 years, typically 4⁷. The details of Level 7 ones [34] were only just approved at the time of writing, so it is hard to see how they will work in practice. However, the entire Degree Apprenticeship mechanism does seem to be geared more to large companies capable of supporting a bespoke programme, as for example is happening in Accountancy, where the "Big Four" firms are enthusiastically supporting such programmes⁸. How well it can adjust to smaller high-technology companies has yet to be seen.

3.3 Sandwich Years

In the UK context, a university course that includes a period working in industry (which may include government, charities, etc.) is generally called "sandwich", and in North America the term "co-op" is generally used. The most common model in Computing in England, where the vast majority of students study three-year Bachelor's degrees, is a year's placement in industry between the second and final years of study. This is remarkably successful in computing. The University of Bath has run such courses since its founding (1966), with about 80% of students opting to take the sandwich year. There is statistical evidence for its success wherever it is used in the UK⁹:

"...those studying sandwich courses enjoy the lowest levels of unemployment (6% sandwich vs 15% non-sandwich), the lowest levels of non-graduate level employment (6% sandwich vs 25% non-sandwich), and graduates

from sandwich courses are twice as likely to be earning over £20,000 compared to those who did a standard degree." [47]

A simplistic remedy would be to require that all students study sandwich degrees, but this has numerous challenges:

- (1) Some students do not wish to, often for valid reasons;
- (2) The supply of employers willing to offer such placements is limited, and often they are only offered to a limited number of universities with whom the employer has built up relations, often going back decades;
- (3) The university needs to invest in the process: a successful sandwich year programme is not a matter of simply allowing students to intermit their studies.

Hence we should ask ourselves *why* such courses are so successful (if indeed they are: there is a possible confounding factor, in that, for those universities with scanty support for the sandwich system, those students that do take a sandwich year will tend to be the more self-motivated ones, who would probably do well anyway).

There appears to be two classes of reasons: those intrinsic to the sandwich process, and the skills the sandwich process confers. The first class is easy to understand: the employer can view the year as a year-long assessment phase before deciding whether to offer a permanent job. From the authors' institutional experience, about 2/3 of sandwich placements result in job offers to the student. However, it is the second class that we need to investigate in the hope that non-sandwich courses can learn from them.

4 THE INSTITUTE OF CODING

4.1 Structure

Formally announced in 2018 [23], but foreshadowed in 2015 [28], the Institute of Coding¹⁰ is one of the UK Government's latest responses to the "digital skills challenge" [14]. The Institute brings together a consortium¹¹ of research- and teaching-focused universities (primarily based in England due to the origin of the core funding, along with two Welsh institutions co-funded through a separate mechanism), large corporates, small- and medium-sized enterprises (SMEs), established industry groups, experts in the delivery of distance/non-traditional learning and professional bodies to

⁷One such is detailed at <http://www.aston.ac.uk/study/degree-apprenticeships/employers/degree-apprenticeship-programmes/digital-and-technology-solutions-degree-apprenticeship/>

⁸For example: <https://www.pwc.co.uk/careers/school-jobs/jobs/flying-start-degrees.html>

⁹And at least anecdotal evidence elsewhere: "the co-op system is a major reason for our [University of Waterloo] success" [51].

¹⁰<https://instituteofcoding.org>

¹¹For full list of IoC partners, see: <https://instituteofcoding.org/partners/>

develop and deliver innovative, industry-focused education across the UK. It is explicitly an industry–university collaboration, with the Government contributing at most 50% of the project funding.

It brings together for the first time traditional computer science departments and business schools, leaders in art and design, innovation in programme delivery, the industry backing of the UK’s leading digital employers, and the leading professional bodies. The Institute’s vision is that “every student leaves education with employment, and that employers and individuals across the UK have ready access to the skills they need to compete successfully in the global digital economy”. It is structured around five priority themes¹²:

4.2 “University Learners”

To increase the number of university learners and improve employability through innovative learning methods:

This is aimed at understanding, and solving, the various “Skills Mismatch” problems to increase the number of university learners at Levels 6 and 7 (especially in key national priority areas such as data science and cyber security); as discussed previously, these problems can be quite subtle, and are not addressed by such broad requirements as [4, Requirement 2.3.1]. However, this theme aims to increase graduate employability via stronger employer links; hence the Institute is also looking at accreditation, with a view to producing more detailed records, essentially e-portfolios, of skills achieved, embedding innovative learning methods into material and delivery across institutions.

4.3 “The Digital Workforce”

To create learning that meets employer needs, enriches the student experience and provide in-work and flexible learning options that are viable at scale:

This theme aims to explore alternative delivery models, in an effort to identify and synthesise best practice – for both specialist and generalist provision, as well as educational training and professional development. There is a strong theme of lifelong learning: it aims to champion the role of the university as a teaching and learning partner/provider to equip learners for a career rather than specific jobs. In practice this is likely to be largely aimed at degree apprenticeships (see §3.2) in the short to medium term, to draw in more universities to provide Degree Apprenticeships and other related course models. These are still in their very early days in computing, and we hope that the Institute will enable best practice sharing from the beginning. In terms of content, as opposed to pedagogic practice, this theme is tightly linked with theme 1, notably in areas like Cyber security, where there is a great shortage of non-proprietary teaching material.

4.4 “Digitalising the Professions”

To develop learning to address sector-specific digital skills needs, build an industrial strategy and deliver modular training:

This theme aims to develop a new industry-facing market of university-led, industry-valued provision in areas of strategic importance. The official description “to transform professions undergoing digital transformation” [23] is tautologous, but the consortium aims are to provide a flexible modular digital masters programme aimed at people in various professions where digital technologies are changing the job. Especially in sectors where serious upskilling is necessary (for example, across the creative economy, automotive, manufacturing, healthcare, the financial sector, etc), and also to provide various short taster courses in order to widen the reach of digital skills. As for theme 2, this will be sharing content with theme 1.

4.5 “Widening Participation”

To develop a path from first contact to employment, removing barriers to entry and progress for poorly-served groups:

This is aimed at addressing the with systemic issues with gender and diversity, as identified at the start of this paper: creating a pipeline, with tailored, inclusive curricula. Since the Institute bid was submitted and approved, salary data [24] (see Figure 1) has been released, which show the importance of a more nuanced study of the effect of gender in particular. The UK Government analysis [24] concentrated on gender, but we are hoping to do similar studies for computer science with regard to other protected characteristics such as ethnicity, to better understand and address the barriers, to share best practice across the sector.

4.6 “Knowledge Sharing and Sustainability”

To horizon scan for future digital skills need, disseminate and share best practice of the project, look at long-term sustainability and the management of the programme:

This theme is an underpinning theme for the others, providing longer-term horizon scanning, as well as supporting the evidence base, policymaking and sustainability through a “Digital Skills Observatory”. A perverse, but totally natural, consequence of the REF has been the marginalisation of pedagogy research in the UK [11]. This is particularly acute in Computing, and can be quantified by noting that Australia, with less than 40% of the population of the UK, sends practically the same number of papers to the Koli Calling conference in Finland as the UK does [44]. Dissemination of good practice is also low: a 2016 national survey [36] was the first of its kind in the UK, despite the fact that they had been running for many years elsewhere [45].

4.7 Key Challenges

Delivering as much education as the Institute proposes presumes a supply of educators; this is a major challenge at all levels for computing in the UK [6], as it is in many countries. We have seen a number of challenges in the recruitment and retention of pre-university teachers (especially in England [43]), as well as issues with effectively scaling professional development opportunities at the national level [41] (for example, subject knowledge enhancement, pedagogic knowledge, as well as funding to access courses

¹²<https://instituteofcoding.org/about-the-ioc/>

and higher degree programmes [42]); hence one workpackage in this theme is devoted to “educating the educators”.

A further challenge is sustainability. The Government funding for the Institute is relatively short-term given the systemic challenges, and indeed will lapse before anyone graduates from a Level 6 (undergraduate/BSc) degree apprenticeship. Hence the Institute needs to build an ecosystem with its academic and industrial partners to become self-supporting in a very short timeframe.

5 IMPACT TO DATE

The Institute of Coding is very much “work in progress”: at the time of writing it was just one year on from the official launch announcement. With numerous activities and initiatives – at both the regional and national level – cutting across all five work themes. It has an implicit aim to provide a national cohering role – especially at post-compulsory level – collaborating with other organisations working on school-level interventions to create the sustainable ecosystem to address the challenges articulated in this paper.

There are new courses already started, or planned to start in 2019, badged as “Institute of Coding”, mostly Degree Apprenticeships, Masters courses, or joint Masters courses and (Level 7) Degree Apprenticeships. It could be argued that some, particularly the Degree Apprenticeships, might have been started without the Institute of Coding, but it is certainly the case that the Institute of Coding has accelerated the process, not least by short-circuiting the often labyrinthine “quality assurance” processes in universities, as university leadership, prompted (to say the least) by the money on offer, had already signed up to the principle.

From an underpinning research and evidence-base perspective, the announce of the Institute in 2015 [28] prompted the baseline research on introductory programming in UK universities [36, 45], alongside a significant renewed focus on computer science education in the UK – research, policy and practice – further reinforced by the Royal Society’s recommendations in its 2017 report on computing education [40].

6 FUTURE WORK AND REPLICABILITY

We are now seeing a number of successful initiatives, activities and interventions which may prove useful to other nations reforming their curricula (both compulsory school-level, as well as post-compulsory), as well as in the wider aim of developing broader – sustainable and transferable – societal digital skills. However, we recognise that there has been a significant corpus of activity in this space, both in the UK and internationally – from existing alternatives such as microdegrees, MOOCs, coding universities, industry-specific university-industry coding collaborations, boot camps, etc – with a multitude of initiatives purporting to fix the problem; it is thus important not to replicate past failures.

When establishing a model for viewing computer science education, it is apparent that there is substantial diversity between education systems – from formal school curricula through to tertiary education, as well as wider education policy and funding – and this can create obstacles when trying to understand progress made in one country and potentially replicate it in another [33]. This is particularly relevant to the devolved (and diverging) educational

systems of the UK, as well as the variety of its disparate interventions, especially formal curricula and post-compulsory/tertiary education. There remain significant challenges, particularly around connectedness and coherency of policy, as well as bridging the gap between the expectations and evolving requirements of (higher) education and industry.

However, two overarching themes are apparent; firstly, such effort has to be viewed as a coordinated multi-pronged approach, requiring an overarching holistic strategy, working collaboratively with universities, colleges, employers including but not limited to industry, local and national government, as well as young people, parents and the wider public. Secondly, there is a need to overcome the challenges of recurrent funding and support to ensure long-term sustainability of the interventions – across the four nations of the UK – as well as ensuring parity of opportunity for all young learners. Whilst we do not necessarily recommend replicating some of the policy structures under which the UK operates, especially national quality assessment exercises such as the TEF, they can provide a useful policy lever for initiatives such as the Institute.

The Institute of Coding thus aims to provide a national cohering role, collaborating with other organisations working on school-level interventions (such as the recently-announced £84m National Centre for Computing Education¹³ in England, Computing At School (CAS), Raspberry Pi Foundation, Technocamps, *et al.* in the UK), providing a platform for conducting research activities; building the evidence base and informing policy; supporting accreditation and standards; as well as changing the wider perception – and economic, societal and cultural importance – of ‘ICT’, ‘digital’, ‘coding’ and other cognate areas.

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REFERENCES

- [1] Marc Andreessen. 2011. Why Software Is Eating The World. *The Wall Street Journal* (August 2011). Available online: <https://www.wsj.com/articles/SB10001424053111903480904576512250915629460>.
- [2] Stuart Arthur, Tom Crick, and Janet Hayward. 2013. *The ICT Steering Group’s Report to the Welsh Government*. Technical Report. <http://learning.gov.wales/resources/browse-all/ict-steering-groups-report/?lang=en>.
- [3] BBC. 2018. Which university courses boost graduates’ wages the most? <https://www.bbc.co.uk/news/education-44413086>. (2018).
- [4] BCS, The Chartered Institute for IT. 2018. Guidelines on course accreditation. <https://www.bcs.org/category/7066>. (2018).
- [5] Neil C. C. Brown, Michael Kölling, Tom Crick, Simon Peyton Jones, Simon Humphreys, and Sue Sentance. 2013. Bringing Computer Science Back Into Schools: Lessons from the UK. In *Proc. 44th ACM Technical Symposium on Computer Science Education (SIGCSE 2013)*. ACM, New York, 269–274.
- [6] Neil C. C. Brown, Sue Sentance, Tom Crick, and Simon Humphreys. 2014. Restart: The Resurgence of Computer Science in UK Schools. *ACM Transactions on Computer Science Education* 14, 2 (2014), 1–22.
- [7] Erik Brynjolfsson, Daniel Rock, and Chad Syverson. 2018. *The Economics of Artificial Intelligence: An Agenda*. National Bureau of Economic Research, Chapter Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics.
- [8] C. Callender and G. Mason. 2017. Does Student Loan Debt Deter Higher Education Participation? New Evidence from England. *The Annals of the American Academy of Political and Social Science* 671 (2017), 20–48.

¹³<https://teachcomputing.org/>

- [9] C.M. Campbell, M. Jimenez, and C.A.N. Arrozal. 2018. Prestige or education: college teaching and rigor of courses in prestigious and non-prestigious institutions in the U.S. To appear in *Higher Education* (2018).
- [10] CECE. 2017. *Informatics Education in Europe: Are We All In The Same Boat?* Technical Report. The Committee on European Computing Education, jointly established by Informatics Europe & ACM Europe.
- [11] D.R.E. Cotton, W. Miller, and P. Kneale. 2018. The Cinderella of academia: Is higher education pedagogic research undervalued in UK research assessment? *Studies in Higher Education* 43 (2018), 1625–1636. Issue 9.
- [12] Tom Crick and Faron Moller. 2015. Technocamps: Advancing Computer Science Education in Wales. In *Proc. 10th International Workshop in Primary and Secondary Computing Education (WiPSCe 2015)*. ACM, New York, 121–126.
- [13] Tom Crick and Sue Sentance. 2011. Computing At School: Stimulating Computing Education in the UK. In *Proc. 11th Koli Calling International Conference on Computing Education Research*. ACM, New York, 122–123.
- [14] James H. Davenport, Tom Crick, Alan Hayes, and Rachid Hourizi. 2019. The Institute of Coding: Addressing the UK Digital Skills Crisis. In *Proc. Computing Education Practice 2019*. ACM, 10:1–10:4.
- [15] James H. Davenport, Alan Hayes, Rachid Hourizi, and Tom Crick. 2016. Innovative Pedagogical Practices in the Craft of Computing. In *Proc. 4th International Conference on Learning and Teaching in Computing and Engineering (LaTiCE 2016)*. IEEE, 115–119.
- [16] Department for Business, Energy and Industrial Strategy. 2017. *Industrial Strategy: building a Britain fit for the future*. Technical Report White Paper. UK Government.
- [17] Department for Business, Innovation and Skills. 2010. The Browne report: higher education funding and student finance. <https://www.gov.uk/government/publications/the-browne-report-higher-education-funding-and-student-finance>. (2010).
- [18] Department for Business, Innovation and Skills. 2011. The Returns to Higher Education Qualifications. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32419/11-973-returns-to-higher-education-qualifications.pdf. (2011).
- [19] Department for Business, Innovation and Skills. 2015. Government rolls-out flagship Degree Apprenticeships. <https://www.gov.uk/government/news/government-rolls-out-flagship-degree-apprenticeships>. (2015).
- [20] Department for Digital, Culture, Media & Sport, UK Government. 2017. DCMS Sectors Economic Estimates 2017: Employment. <https://www.gov.uk/government/statistics/dcms-sectors-economic-estimates-2017-employment>. (2017).
- [21] Department for Education. 2013. National curriculum in England: computing programmes of study. <https://www.gov.uk/government/publications/national-curriculum-in-england-computing-programmes-of-study>. (2013).
- [22] Department for Education. 2017. Longitudinal Education Outcomes (LEO) Data Set. <https://www.gov.uk/government/statistics/graduate-outcomes-longitudinal-education-outcomes-leo-data>. (2017).
- [23] Department for Education. 2018. Prime Minister announces £20 million Institute of Coding. <https://www.gov.uk/government/news/prime-minister-announces-20-million-institute-of-coding>. (2018).
- [24] Department for Education. 2018. Undergraduate degrees: relative labour market returns. <https://www.gov.uk/government/publications/undergraduate-degrees-relative-labour-market-returns>. (2018).
- [25] European Commission. 2018. *Digital Single Market Scoreboard: United Kingdom*. Technical Report. DG CONNECT. <https://ec.europa.eu/digital-single-market/en/scoreboard/united-kingdom>.
- [26] N. Friesen. 2008. Critical Theory: Ideology Critique and the Myths of E-Learning. *Ubiquity* 2008, June, Article 2 (June 2008). <https://doi.org/10.1145/1386858.1386860>
- [27] Higher Education Statistics Agency. 2018. Higher Education Leavers Statistics: UK, 2016/17 - Salary and location of leavers in employment. <https://www.hesa.ac.uk/news/28-06-2018/sfr250-higher-education-leaver-statistics-employment>. (2018).
- [28] HM Government. 2015. Chancellor’s speech to GCHQ on cyber security: Chancellor lays out new plan for £1.9 billion cyber investment, and details seven more departments that have settled ahead of the Spending Review. <https://www.gov.uk/government/speeches/chancellors-speech-to-gchq-on-cyber-security>. (2015).
- [29] HM Revenue & Customs. 2016. Apprenticeship Levy. <https://www.gov.uk/government/publications/apprenticeship-levy/apprenticeship-levy>. (2016).
- [30] House of Commons Science and Technology Committee. 2016. *Digital Skills Crisis*. Technical Report HC 270. UK Parliament.
- [31] House of Lords Select Committee on Communications. 2017. *Growing Up with the Internet*. Technical Report HL 130. UK Parliament.
- [32] House of Lords Select Committee on Digital Skills. 2015. *Make or Break: The UK’s Digital Future*. Technical Report HL 111. UK Parliament.
- [33] Peter Hubwieser. 2013. The Darmstadt model: A first step towards a research framework for computer science education in schools. In *Proc. ISSEP 2013*. 1–14.
- [34] Institute for Apprenticeships. 2018. Digital and technology solution specialist (degree). <https://www.instituteforapprenticeships.org/apprenticeship-standards/digital-and-technology-solution-specialist-degree/>. (August 2018).
- [35] Faron Moller and Tom Crick. 2018. A University-Based Model for Supporting Computer Science Curriculum Reform. *Journal of Computers in Education* 5, 4 (2018), 415–434.
- [36] Ellen Murphy, Tom Crick, and James H. Davenport. 2017. An Analysis of Introductory Programming Courses at UK Universities. *The Art, Science, and Engineering of Programming* 1(2), 18 (2017), 18–1–18–23.
- [37] OECD. 2002. *Measuring the Information Economy*. Technical Report. Organisation for Economic Co-operation and Development.
- [38] OECD. 2016. *Education at a Glance 2016: OECD Indicators*. OECD Publishing, Paris. <http://dx.doi.org/10.187/eag-2016-en>
- [39] Office of National Statistics. 2009. UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007). <https://www.ons.gov.uk/methodology/classificationsandstandards/ukstandardindustrialclassificationofeconomicactivities/uksic2007>. (2009).
- [40] Royal Society. 2017. *After the reboot: computing education in UK schools*. Technical Report. Royal Society.
- [41] Sue Sentance and Andrew Csizmadia. 2017. Computing in the curriculum: Challenges and strategies from a teacher’s perspective. *Education and Information Technologies* 22, 2 (2017), 469–495.
- [42] Sue Sentance, Mark Dorling, Adam McNicol, and Tom Crick. 2012. Grand Challenges for the UK: Upskilling Teachers to Teach Computer Science Within the Secondary Curriculum. In *Proc. WiPSCe 2012*. ACM, 82–85.
- [43] Sue Sentance and Jane Waite. 2018. Computing in the classroom: Tales from the chalkface. *it-Information Technology* 60, 2 (2018), 103–112.
- [44] Simon. 2016. The Koli Calling Community. In *Koli Calling 2016*. ACM, New York, 101–109.
- [45] Simon, Raina Mason, Tom Crick, James H. Davenport, and Ellen Murphy. 2018. Language Choice in Introductory Programming Courses at Australasian and UK Universities. In *Proc. 49th ACM Technical Symposium on Computer Science Education (SIGCSE 2018)*. ACM, New York, 852–857.
- [46] Sir Bill Wakeham. 2016. Wakeham Review of STEM Degree Provision and Graduate Employability. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518582/ind-16-6-wakeham-review-stem-graduate-employability.pdf. (2016).
- [47] Sir Nigel Shadbolt. 2016. Shadbolt Review of Computer Sciences Degree Accreditation and Graduate Employability. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/518575/ind-16-5-shadbolt-review-computer-science-graduate-employability.pdf. (2016).
- [48] Tech Nation. 2018. UK Tech Nation Report 2018. <https://technation.io/insights/report-2018/>. (2018).
- [49] Theo Tryfonas and Tom Crick. 2018. Public Policy and Skills for Smart Cities: The UK Outlook. In *Proc. 11th International Conference on Pervasive Technologies Related to Assistive Environments (PETRA 2018)*. 116–117.
- [50] UK Commission for Employment and Skills. 2015. Sector insights: skills and performance challenges in the digital and creative sector. <https://www.gov.uk/government/publications/sector-insights-skills-and-performance-challenges-in-the-digital-and-creative-sector>. (2015).
- [51] Stephen Watt. 2017. Value of co-op year. Private communication to JHD. (2017).