

The Institute of Coding: A University-Industry Collaboration to Address the UK 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 in the higher education/workforce domain at the same time as substantial levels of computer science curriculum reform across the four nations of the UK – especially in England, with a new computing curriculum that first started in 2014, in which all children are expected to learn two programming languages, as well as wider computer science fundamentals and develop transferability computational thinking skills.

In this paper, we describe the background and evidence base for the Institute of Coding, its key themes and current activities, as well as reflecting on 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 we see or making decisions that affect us every day; to education, health and social care, and innovation in public services [26].

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 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 we may the UK may have a traditional vertical ‘IT and Telecoms’ sector, we also have 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 not unique to the UK, it is perhaps exemplified by some of the grand challenges identified as part of the 2017 UK Industrial Strategy [17]: from precision medicine, manufacturing and future materials, to creative industries clusters and next generation services, through to driverless cars and smart cities [48].

1.2 Diversity, especially Gender

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 [21]. 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 [47]. Indeed, the Institute of Coding announcement [24] quoted the even more pessimistic “In 2017, female programmers and software developers made up just 3.9 per cent of tech and telco professionals in the UK”.

¹Despite the debunking in [27].

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1.3 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 [12]. 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 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 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 wider public perceptions of the discipline.

Alongside substantial curriculum reform across the UK [8, 9], including a new national curriculum in England [22] and emerging reform in Wales [3, 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 [41] 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 connectedness and policy coherency – more so when it cuts across ministerial portfolios, or requires multi-year coordinated support. In this paper we frame some of these discrete 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.

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 Sections 3 and 4 by the UK higher education policy context and the skills mismatch respectively; in Section 5 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.

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. [49, 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 profitable for the individual: according to [19, Figure 4], “mathematical and computer sciences” have the second highest earnings return of all subjects (beaten only by “medicine and dentistry”). The country profits from this as well: according to [19, p. 16], this is, per head, the fourth most beneficial subject to the UK. Despite the headline success in [19], the employment figures are not great, and the earnings data are patchy.

2.1 Graduate Employment

Quoting [49], the author of a UK Government-commissioned report [46] writes:

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” [46, ¶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).

Mature, BME and LPN students all find getting jobs more difficult.

However, for those students that do find jobs, the data are better, showing [46, 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 [25], and presented to the public in [4], which also allows the reader to break down the data by university and subject.) is even less clear on a microscopic level, though on a macroscopic level it bears out much of what [46] said.

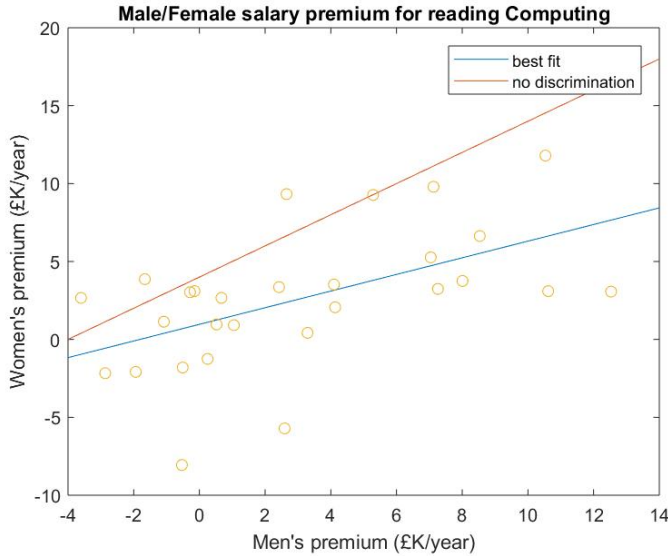
On the macroscopic level, the reader should consider [25, Table 5]. We focus on the ‘Men’ data as presented here, as there are (regrettably) many more than there are women in the cohorts, though the effects are similar. An OLS (“Ordinary Least Squares”) fit shows that a man reading Computing would earn 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

²11.7% six months after graduation (the standard UK measure) at the time of [46], compared with a STEM average of 8.4%. Note, however, that Computing is 20% of STEM [45, Table 1], so ‘STEM-less-Computing’ has a 7.6% unemployment rate.

³STEM is “Science, Technology, Engineering, Mathematics” for [46] and this paper.

⁴Clearly not the only measure of job quality, or contribution to society, but at least it’s measurable, and has been measured in the LEO dataset [23], which tracks individuals through school, university and into the labour market, combining educational, tax and benefits data.

Figure 1



into account. For reasons explained in [25, §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 [25, Figure 15] to fourth best [25, Figure 17], and for women it moves to seventh best [25, 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 [25, 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.

2.3 Per-University Earnings

[4] allows one to break down the data underpinning [25], 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 shown in Figure 1.

3 UK HIGHER EDUCATION POLICY CONTEXT

It is worth recalling that, after the Government’s acceptance of the Browne report [18], 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 [10] 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 the 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 [11]. 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 HE provision for each Higher Education provider within the United Kingdom. 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 assessment of teaching as such, merely statistical data such as that used in [46].

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, the latest being the Browne report [18], 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” [20]. 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.

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 the 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 from the Government.

Degree Apprenticeships can be either "Level 6" (BSc. level) or "Level 7" (MSc. level)". The Level 6 ones last 3–5 years, typically 4. One such is detailed at <http://www.aston.ac.uk/study/degree-apprenticeships/employers/degree-apprenticeship-programmes/digital-and-technology-solutions-degree-apprenticeship/>. The Government has yet to approve the details of Level 7 ones, so not much can be said.

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 [16, 36, 44]. One of the main challenges for the university community is to better understand this complaint.

4.1 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 UK⁷:

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. [46, ¶2.5]

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

- (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;

⁷And at least anecdotal evidence elsewhere: "the co-op system is a major reason for our [University of Waterloo] success" [50].

- (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 are, it seems to the authors, 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. Bath's experience is that 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. A major one, brought out repeatedly by students returning from placement, is team working.

4.2 Team/Group working

"Teamwork" is often identified as a key skill [2, and many others]. Simplistically, then, universities should teach it. Indeed, the British Computer Society has long required this of degrees it accredits:

An ability to work as a member of a development team recognising the different roles within a team and different ways of organising teams [7, Requirement 2.3.1].

The problem is that group working is unpopular with students. Most of them have never experienced it in their academic work at school, and really dislike "being dragged down", as they generally put it, by others. In many countries, this wouldn't matter, but the UK has (many would say "suffers from", see, e.g. [15]) the National Student Survey [5]. The results of this, notably the headline "are you satisfied with your course" question, are pored over intently by university management [5, Myth 3]. As well as the quantitative scores, the students submit free-text responses, and it does not take many students complaining about the group work before the Pro-Vice-Chancellor (Teaching) or equivalent⁸ is beating down the Director of Studies door, saying "obviously you must abolish group work immediately". The first three authors have been Directors of Studies, and can vouch for this.

However, a BCS-accredited course gives the response "but our accreditation demands it", whereupon the discussion can evolve into a more sensible debate about the size, shape and process of group working.

This leads to a curious paradox. Employers value group working experience (at a Shadbolt Review focus group, every employer stated they always asked potential employees about experience of group working), group working experience is only taught because accreditation requires it, but employers do not value accreditation. "systems of accreditation more broadly are poorly understood and valued by employers, students and HE providers" [46, ¶2.12].

⁸Whose pay may well be linked to these scores.

4.3 Code Review

A further aspect of the “not industry ready” complaint has recently been identified by the Institute of Coding team as part of the engagement with industry, and is described by a prominent industrialist from the safety-critical sector as follows.

We do find we have to train grads how to review stuff properly — both personal (their own stuff) and team/peer reviews. While they may have been exposed to the concept of personal and peer reviews, none of them have actually been taught how to do it properly and how to measure its effectiveness. [13]

This quote is supported by many Institute of Coding industrialists, and also by the work of [6], though their conclusion “Code quality should be discussed more thoroughly in educational programs” is probably too weak. As [13] says “While they may have been exposed to the concept of personal and peer reviews” it is unlikely that many of them will actually have practiced it. One might ask “but what about the group working”?

That is a good question, and one that the Institute of Coding is investigating. A provisional answer lies in the nature of group working. Practically all BCS-accredited universities meet the requirement [7, Requirement 2.3.1] (and “working with others” [7, Requirement 2.3.2]) by means of a group practical project. This is practically always done before the final year, both for reasons of balance (BCS also requires an individual project amounting to at least 25% of the final year [7, Requirement 2.5.1]) and, more pragmatically, so that the memory of this disliked experience will have worn off before the students complete the National Student Survey in their final year. Universities with a strong sandwich programme also want students to be at least engaged on a group project when they go to their interviews.

But students hate being “dragged down” by their fellow team-members (it is odd that Directors of Studies and group project lecturers hear far less about being “dragged up”!). Hence students are very keen to have “their own bit” of the group activity, and it is difficult to have true team responsibility and code reviews. Various attempts are being made at this, e.g. at Bath the use of “Agile” methodology with testing formally built into the set of sprints, but it is probably fair to say that this is an under-researched area. [34] is one of the few pieces of research, but they say “In future research, we would like to systematically investigate best practices for building effective P[edagogical]C[ode]R[evue] teams”.

5 INSTITUTE OF CODING

Formally announced in [24], but foreshadowed in [28], the Institute of Coding⁹ is one of the UK Government’s latest responses to the “Digital Skills Challenge”. The Institute brings together a consortium of research- and teaching-focused universities (primarily based in England due to the origin of the core funding, as well as 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 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 money.

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 themes:

5.1 “University Learners”

This is aimed at understanding, and solving, the “Skills Mismatch” problems (see §4). As seen from §4.3, these problems can be quite subtle, and are not addressed by such broad requirements as [7, Requirement 2.3.1]. Hence the Institute is also looking at accreditation, with a view to producing more detailed records, essentially e-portfolios, of skills achieved. It is possible that these will be supported by a blockchain-based mechanism, as is being done elsewhere [40].

5.2 “The Digital Workforce”

In practice this is largely aimed at degree apprenticeships (see §3.2). 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 CyberSecurity, where there is a great shortage of non-proprietary teaching material.

5.3 “Digitalising the Professions”

The official description “to transform professions undergoing digital transformation” [24] 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 such that serious upskilling is necessary, 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.

5.4 “Widening Participation”

This is aimed at the problems identified in §1.2. Since the Institute bid was submitted, the salary data in [25] (see Figure 1) have been released, which show the importance of a more nuanced study of the effect of gender in particular. The analysis in [25] concentrated on gender, but we are hoping to do similar studies for computer science with regard to other characteristics such as ethnicity.

5.5 “Knowledge Sharing and Sustainability”

A perverse, but totally natural, consequence of the REF has been the marginalisation of pedagogy research in the UK [14]. 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 [43]. Dissemination of good practice is

⁹<https://instituteofcoding.org>

also low: [36] was the first survey of its kind in the UK, despite the fact that they had been running for many years elsewhere [44].

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 [9], as it is in many countries. We have seen a number of challenges in the recruitment and retention of teachers and funding to access courses 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 very short-term, and indeed will lapse before any one graduates from a Level 6 (BSc.) degree apprenticeship. Hence the Institute needs to become self-supporting in a very short time-frame.

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, 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.

The Institute of Coding is very much “work in progress”: at the time of writing it was less than nine months old. The mere adumbration [28] prompted the research in [36], and the various working groups round the themes are causing more discussion of computing pedagogy in the UK than the authors can ever remember, further reinforced by the recommendations in [41].

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 could thus provide a national cohering role, collaborating with other organisations working on school-level interventions (such as 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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