


THE DIGITAL REVOLUTION

The impact of the **Fourth Industrial Revolution** on employment and education




Edge Foundation

Champion of technical, practical and vocational learning

Kenneth Baker
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Foreword by Sir Anthony Seldon

We are sleepwalking – Government, schools and universities – into the biggest potential disaster of modern times.

The nature and number of jobs is set to change dramatically, as this visionary booklet outlines. In 2015, the Bank of England estimated that up to 15 million jobs in Britain are at risk. Societies with large numbers of jobless are unhappy, dangerous places.

Yet schools and universities continue to trot out their twentieth-century, nineteenth even, formulae. Economic revolutions in the past, they say, have always been advantageous; this one will be no different. Ah, but it will be. Very different.

Professor David Deming at the Harvard Graduate School of Education and a faculty research fellow at the National Bureau of Economic Research in the USA, has argued convincingly that the very skills prioritised by linear thinking schools and universities are precisely the ones that algorithms are able to perform much quicker, more profoundly and reliably than humans.

We need to focus far more, if we are to prepare our young for tomorrow's economy, and to optimise its infinite possibilities, on active as opposed to passive learning, on technical entrepreneurial skills, on personal and collaborative skills that teach us how to live intelligent and fulfilling lives, and how to work and live harmoniously with others.

There is no time to waste, as this seminal booklet makes abundantly clear.

Sir Anthony Seldon is a political historian, author and commentator on education and contemporary Britain. His first degree was PPE from Worcester College Oxford, his PhD was from LSE, where he became a Research Fellow. He has honorary fellowships, doctorates and chairs from a variety of universities, including Birmingham, King's College London, and Buckingham itself. He has written or edited over 35 books including some of the most interesting biographies of Britain's last four Prime Ministers – John Major, Tony Blair, Gordon Brown and David Cameron. He founded the Institute of Contemporary British History, the UK's leading centre for research and study into contemporary British history, with Lord Hennessy and Action for Happiness with Lord Layard. He is a governor at the Royal Shakespeare Company and advisor to a wide variety of governmental and charitable institutions. He is honorary historian of Downing Street.

He started his life as a teacher in 1983 and ten years later was appointed Acting Headmaster of St Dunstan's in South London, and in 1999 the Headmaster of Brighton College which he drove up the league table of examination results, making it one of the most improved academic schools in the country. In 2006 he moved to Wellington College where he repeated that performance turning it by 2013 into the "best public school" and the "most forward-thinking school". He has written a number of booklets on education seeking ways to improve the basic performance of some of the most underprivileged children and the worst performing schools in our country. Sir Anthony is now the Vice-Chancellor of The University of Buckingham.

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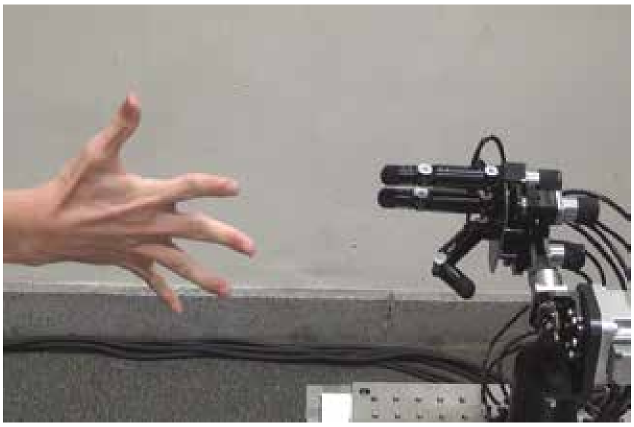
– Kenneth Baker

Tomorrow's technology is already here

From big data to ultra-fast robots, the digital revolution is already happening



Scissors, paper, stone

The Janken robot hand has played rock-paper-scissors with hundreds of humans and won every time. It uses ultra-fast optics to interpret movements in the human player's hand and forms a winning shape in just 20 milliseconds, fifteen times faster than a blink of an eye. The robot was developed by Professor Masatoshi Ishikawa at the University of Tokyo Ishikawa Watanabe Laboratory as a demonstration of robots' ability to react to rapid movement. The technology is likely to have both industrial and military applications.

(image © Ishikawa Watanabe Laboratory, the University of Tokyo)

Robotic Surgery

Laparoscopy – keyhole surgery – has already made a huge difference to many surgical procedures. The next step is the use of remote-controlled robots. The da Vinci® Surgical System, developed by Intuitive Surgical Inc, has helped the Royal Marsden Hospital become the largest provider of robotic surgical procedures in the UK. Surgeons use the equipment to make incredibly accurate, microscopic incisions, greatly improving the patient's treatment and recovery time.

(Image © Intuitive Surgical, Inc)

Artificial intelligence beats a *Go* Master

A computer called Deep Blue famously defeated the chess Grand Master Garry Kasparov in 1997, but it has taken another 19 years for a computer to beat a top-flight *Go* professional. AlphaGo, developed by Google DeepMind in London, played *Go* – an ancient, complex board game – against Lee Sedol in March 2016, winning three out of four sets. AlphaGo was initially fed information from thousands of games played by humans before learning to play the game itself. Its ability to learn from experience depends on laying down vast amounts of data in an artificial neural network.

(Photo courtesy of Google Inc.)

Simulating danger

Flight simulators have been around for many years, allowing pilots to practise for emergencies that might never happen. Virtual reality (VR) is increasingly used in other walks of life, too. QinetiQ and Coal Services have developed a 360-degree theatre which immerses trainees in all the sights and sounds of a coal mine to provide ultra-realistic mine safety training. In future, VR will open the way to new ways of training people in fire-fighting, first aid, nuclear decommissioning, deep sea welding and high-tech manufacturing.

(Photo: ©Coal Services Pty Limited)

3D printing: from houses to nanobots

3D printing can be used for all manner of products and components using metal, polymers and even concrete. At one end of the scale, Contour Crafting technology developed by Dr Behrokh Khoshnevis, University of Southern California, can be used to build houses. At the other extreme it is possible to create nanobots small enough to inject into the blood stream. Future applications are limited only by our imagination, which makes it essential for children to learn to use 3D design and technology from primary level onwards.

(Image © Contour Crafting)

Anywhere, anytime: the gig economy

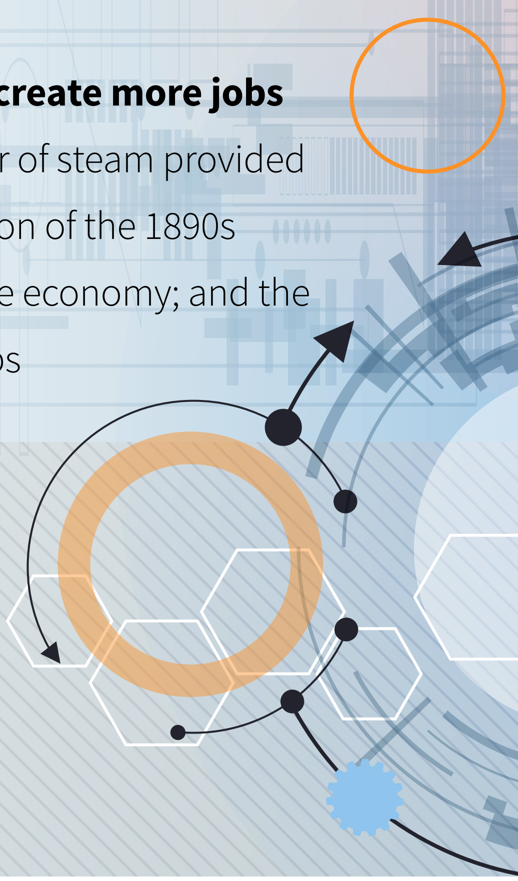
Between 2000 and 2015, the number of British people working for themselves but not employing anyone else rose by 73%, to 1.7 million.* Already common in agriculture and construction, self-employment has grown rapidly in education, health and business services. Mobile communications, cloud computing and virtualisation allow teams to assemble for projects lasting anywhere between a day and several months, without ever meeting face to face. Equally, IT-based businesses like Uber allow people to work for themselves at times to suit themselves.

*Source: Department for Business, Innovation and Skills, Business Population Estimates 2015

The Fourth Industrial Revolution

I have believed up to now that technical revolutions create more jobs than they destroy. In the Industrial Revolution the power of steam provided more jobs than were lost by handworkers; the car revolution of the 1890s created more jobs than were lost by the horse and carriage economy; and the silicon revolution of the 1960s and 1970s created more jobs than were lost in simple clerical and administrative work. When I was a Minister for Information Technology in the early Thatcher years I made several speeches on these lines.

However, I have now come to a different conclusion and I now think that the Digital Revolution – the Fourth Industrial Revolution – will not follow this pattern.



WHY?

First, the pace of technological change is faster than ever. It took ten years for Thomas Newcomen to improve his engine before he showed it to the world in 1712 and its impact on the hand industries was not felt for another sixty years. Today change can come in ten months, ten weeks and even ten days – a three year old iPhone is obsolete. The rate of change in education is also accelerating. It has been estimated that nearly 50% of subject knowledge acquired during the first year of a four year technical degree is outdated by the time the student graduates[1].

Second, the agents of the Digital Revolution are proliferating. The list is long, and already includes artificial intelligence (AI); Big Data; mobile internet; cloud technology; robots in industry and the home; the internet of things; driverless cars, lorries and taxis; drones; 3D printers; nanotechnology; virtual reality, software-based digital therapies and machine learning. By next year – maybe next month – the list will be longer still.

Third, millions of people across the globe have access to huge databases and so experimentation and innovation are not only made in research centres. Significant changes can be made by talented individuals in their homes, offices and factories. The ability of small teams of people to devise new uses, new products and new services has never been greater in the world's history. In the USA 300,000 registrations were made to fly civilian drones during the single month of January 2016[2].

Fourth, very large investments, amounting to billions of dollars, are being made by companies in Europe, Asia and America to develop and implement these agents of

Above: *Argos Distribution Centre at Burton-on-Trent.*
(© Home Retail Group)

change. There is no shortage of capital for this industrial revolution, and one consequence will be a massive reduction in the need for labour. In 2014 $6.5 billion was invested in on-demand start-ups – 10 times the level of 2013 – though there was a slow-down in the final quarter[3].

In 'Rise of the Robots'[4], Martin Ford sums up the challenge in these terms:

> *In the past, automation technology has tended to be relatively specialized and to disrupt one employment sector at a time, with workers then switching to a new emerging industry. The situation today is quite different … Virtually every industry in existence is likely to become less labor-intensive as new technology is assimilated into business models – and that transition could happen quite rapidly.*

Today, it's not just routine and repetitive jobs that are at risk. Algorithms make it possible for computers to sift enormous quantities of information – 'Big Data' – and reach rational conclusions that would have taken people hours or days to work out, leading to the loss of jobs in a whole swathe of service sectors from banking and finance to sales and telemarketing. Computers can read case law faster than lawyers; software reduces the demand for expert accountants – graduate territory. It's even possible to use algorithms to speed up the diagnosis of medical conditions.

However, a recent survey by the Tech Partnership shows that Big Data analytics is the tech occupation with the biggest skills gap, and not just because people lack the necessary technical expertise. According to Nesta …

> *… the problem is finding people with the right mix of skills: the data scientists who combine technical skills, analytical and industry knowledge, and the business sense and soft skills to turn data into value for employers are very hard to find – so much so that some people refer to them as 'unicorns'.*[5]

Rainmaker: Growing numbers of hoteliers are using 'Big Data' to compare their room prices with competitors' rates, predict occupancy up to two months ahead, inform marketing plans and implement special promotions at short notice. One Big Data company, Rainmaker, says hoteliers who use their service in this way have access to data from 150,000 hotel rooms worldwide. They claim their clients achieve revenues 5-10% higher than the average for traditional hotels and gaming hotels.

Source: http://hospitalitytechnology.edgl.com/Libraries/HT-Media/PDFs/htf15_rainmaker.pdf

Agents of disruptive technology

Meanwhile, Toyota is investing $500 million to develop a driverless taxi for San Francisco. Ford's driverless cars are already having road tests and the head of Ford has said that driving with a steering wheel is "as antiquated as wanting to ride a horse"[7]. In 2015, Uber hired an entire team from Carnegie Mellon University in Pittsburgh and created an Advanced Technologies Center nearby – partly to develop its own driverless car[8].

These developments will question the need for car ownership, and ancillary industries like insurance, fuel stations and vehicle maintenance will also be affected.

THE DRIVERLESS ECONOMY

Google's driverless cars have captured the public imagination, but the true revolution starts with Mercedes' driverless lorry.

There are over 3 million truck drivers in the USA and short term prospects look good – there are 20,000 vacancies a year. The introduction of driverless trucks and satellite controlled road trains will change all that. Furthermore, the total number of people employed in the US trucking industry, including those in positions that do not entail driving, exceeds 8.7 million[6]. People working in road-side snack bars, hotels and service stations depend on truckers for custom; but how many will be needed when autonomous vehicles take to American highways?

THE ROBOTIC ECONOMY

General Electric has designed robots to climb and maintain wind turbines. A 3D printer in the Netherlands is building a footbridge over a canal by using long robotic arms and lasers to melt the metal powder – no human hand or girders or concrete foundations needed. A company called Aethon makes mobile robots which work in hospitals delivering medications, lab specimens, food and linens. An even bigger impact will come when robots start to make home deliveries – precisely the aim of Starship Technologies, whose self-driving robots can deliver parcels and groceries anywhere within a 3-mile radius. What's more, they use less energy than most light bulbs.

Top left: ***Mercedes driverless lorry***
(© Mercedes-Benz)

Left: ***Google driverless car***
(© Google)

Right: ***A 3D printer with robotic arms building a pedestrian bridge in the Netherlands***
(© MX3D Joris Laarman Lab)

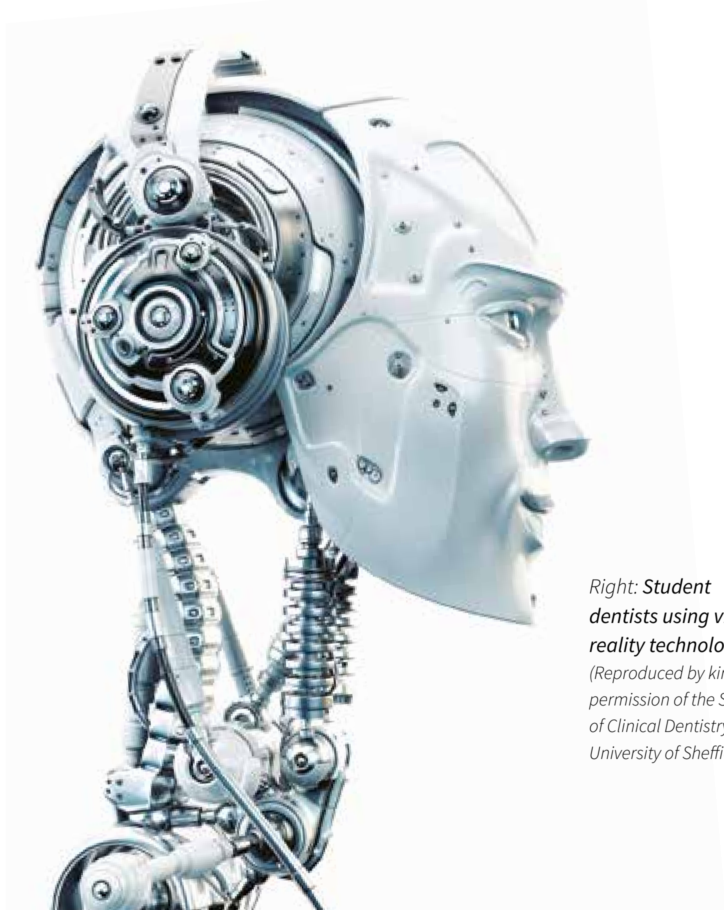
Left: ***Starship Technologies robot delivering packages to small companies in central London***
(©Starship Technologies)

VIRTUAL REALITY

Computer games will take a huge leap forward when virtual reality (VR) headsets become widely available. However, there are also huge opportunities for VR in education and the world of work, ranging from medicine to manufacturing. Virtual Manufacturing Systems enable engineers and designers to collaborate internationally, speeding up product design, development and testing processes at a much reduced cost, and with far less impact on the environment. In an education setting, VR already provides life-like simulations for dentists and engineers: the technology will soon spread to all manner of sectors, occupations and educational institutions.

ARTIFICIAL INTELLIGENCE

Computerisation has already led to the loss of many office jobs. The invention of word processors led to the demise of typing pools. Routine administrative and book-keeping tasks were quickly taken over by machines. Digital photography led to the demise of film processing labs in every high street and the disappearance of such large companies as Kodak.



Right: ***Student dentists using virtual reality technology***
(Reproduced by kind permission of the School of Clinical Dentistry, University of Sheffield)

How will this affect employment and over what timescale?

There have been many well-researched reports which reinforce my concern.

Four of the most significant are:

1. **The Future of Employment**: How susceptible are jobs to computerisation? (2013) by two Oxford dons, Carl Benedikt Frey and Michael Osborne[9]. They suggest that "about 47% of total US employment is at risk" over the next decade or two, affecting routine and middle-income jobs, many of which are currently filled by graduates who did not take a technical degree.

2. **The Bank of England** (2015) took Frey and Osborne's methodology and applied it to the UK economy. The Bank found that up to 15 million jobs are at risk of automation here in the UK[10]. Occupations most at risk include – but are by no means limited to – administrative, clerical and production tasks.

3. **The McKinsey Report on Disruptive Technologies**[11] (2014) suggests that applications of the 12 technologies discussed in the report could have a potential economic impact between $14 and $33 trillion a year in 2025. The authors conclude that as a result, "The nature of work will change, and millions of people will require new skills".

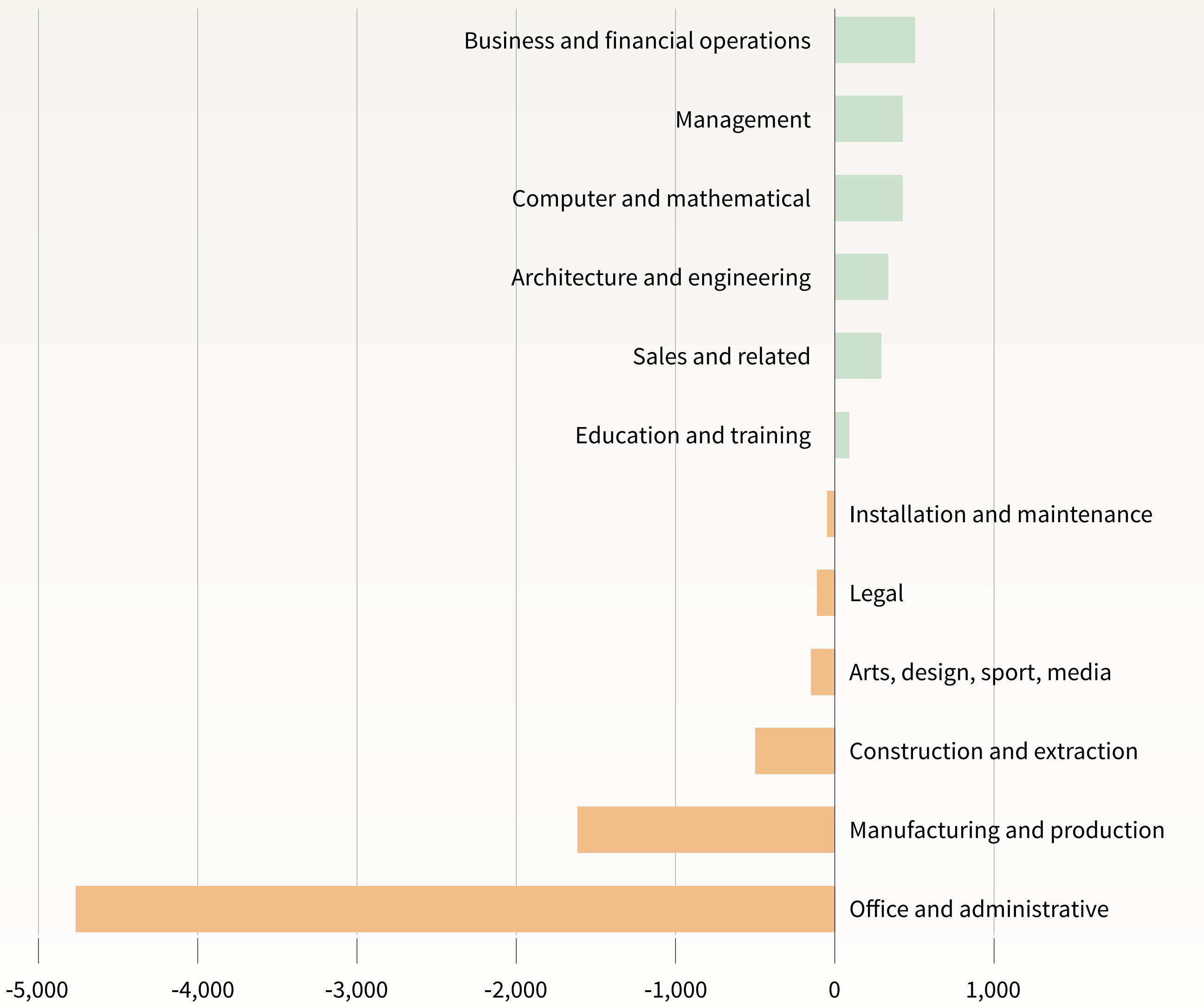
4. **The Future of Jobs**, (2016) published by the World Economic Forum[12] at Davos, covered 15 economies involving 1.86 billion workers grouped into 20 job families. The authors predict "a net employment impact of more than 5.1 million jobs lost to disruptive labour market changes over the period 2015–2020, with a total loss of 7.1 million jobs – two thirds of which are concentrated in the Office and Administrative job family – and a total gain of 2 million jobs, in several smaller job families". Figure 1 (below) illustrates the point very clearly: far more jobs will be lost than created over the next 4-5 years, even more quickly than Frey and Osborne predicted just three years ago.

How will this affect employment and over what timescale?

If proof were needed that massive restructuring is under way, here are just a few recent announcements of redundancies. At the end of 2015, Deutsche Bank announced 9,000 job losses; HSBC 50,000; Lloyds 9,000; Santander 1,900; and Schlumberger 10,000. In the first two months of 2016, Pearson announced 4,000 job losses; Barclays 1,200 (on top of an earlier 7,000); BP 4,000; Virgin Media 900; Shell 4,000 including 500 middle managers; Centrica 4,000; Standard Chartered 15,000; Bombardier 7,000 worldwide, 1,100 in Northern Ireland and 270 in England; the Royal Bank of Scotland 1,200; NPower 2,500, mainly in the north of England; Avon 2,500; the Guardian Media Group 250 and Wolseley 300. Looking ahead, the British Retail Consortiumhas forecast that there could be as many as 900,000 fewer jobs in retail by 2025[13]. The well-respected Wood Review of the petroleum industry has forecast 45,000 more job losses in the North Sea.

The public sector is also reducing staff. Between the start of 2010 and the first quarter of 2015, total public sector employment fell by nearly a million posts (15%). Local government has borne the brunt, losing 640,000 jobs – 21% in five years[14] – but central government is far from immune. The Civil Service headcount fell from 528,000 in the first quarter of 2010 to 440,000 in the same period of 2015, a fall of 16.7%. Nor will the tide turn any time soon: in early 2016, BIS announced that it is closing its Sheffield office and many of the 250 staff will be redundant.

Figure 1: Employment outlook across job families in major economies: net change, 2015-20 (thousands).
Data from World Economic Forum, The Future of Jobs



What will this mean for future jobs?

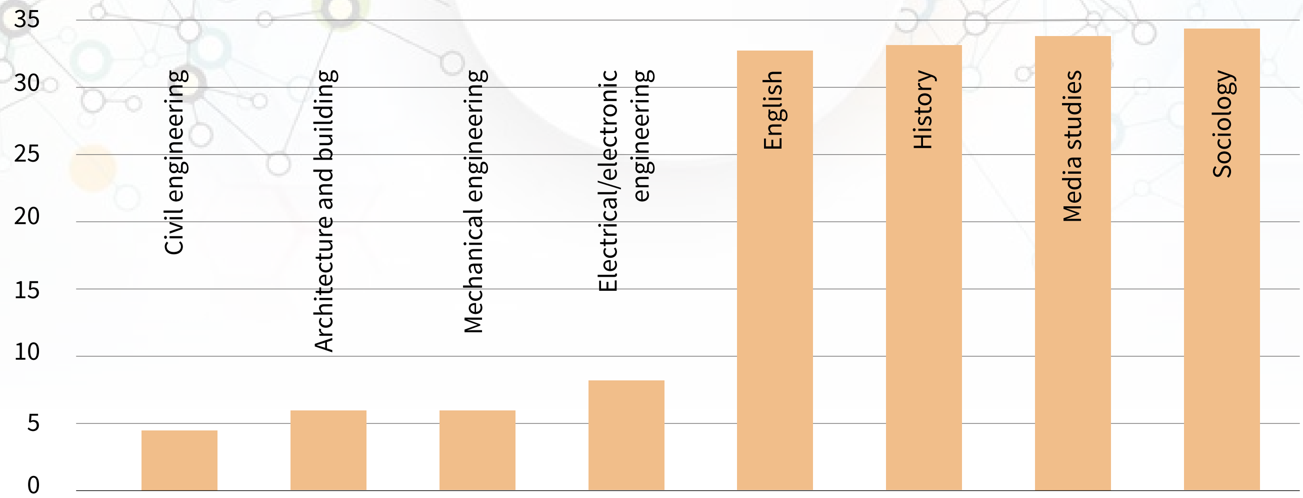
Economists talk about the 'hollowing out' of the labour market. In this scenario, highly-qualified roles are numerous and well-paid. Low-skilled, low-wage jobs (eg in social care) are similarly numerous. Experts point to a gap in the middle where skilled jobs used to be, particularly in manufacturing and in general administration.

It is certainly true that there are more graduates in the labour market than ever before. This is a direct consequence of Tony Blair's policy that 50% of young people should go into higher education. He believed that graduate supply and demand would rise in parallel. In practice, graduate numbers have rocketed, but graduate jobs have not.[15] As a result, a growing number of graduates find themselves under-employed. The problem is especially acute for people with degrees in the arts, social sciences and humanities, and law. It is much less so for graduates in science, technology, engineering and maths (STEM) disciplines. This is illustrated in Figure 2, which shows the proportion of graduates who reported being in retail, catering – flipping hamburgers – and clerical jobs six months after graduating in 2014.

Meanwhile, employers are having great difficulty filling vacancies in the middle ground – the very part of the labour market said to have been 'hollowed out'. The UK Commission for Employment and Skills surveyed over 91,000 employers in 2015 and found that there are significant shortages of 'associate professionals' – people with qualifications just below graduate level – in the construction, retail and financial services sectors. In the skilled trades, shortages are reported in manufacturing, construction, wholesale, retail, hotels and restaurants, transport and logistics, business services and even the arts.

The need for technical and practical skills will not disappear in the digital revolution. In some cases, demand will increase precisely because we need people to create and operate digital and automated systems.

Figure 2: Percentage of 2014 graduates employed in retail, catering and clerical jobs 6 months after graduating in 2014 (selected disciplines)[16]



First, the retail skills needed for the digital era are likely to be computer-based. When I met Sir Charlie Mayfield, Chairman of John Lewis, to discuss University Technical Colleges, I wanted to talk about food processing, because one UTC was considering it as a specialist subject. But he wanted to talk about the lack of computer scientists capable of handling 'Big Data' in his massive logistics operation. One of the consequences of this is that Reading UTC – which specialises in computer science and engineering – already supports higher apprentices at 18 and plans to have advanced apprenticeships in information technology. The JCB Academy UTC has 135 advanced apprentices this term and is planning to move into degree apprenticeships.

Second, we should not under-estimate the continuing importance of non-routine physical tasks. These include the performing, creative and culinary arts, but also making, mending, servicing and adapting single objects and artefacts or short runs of bespoke products. These operations might take place in a single location, such as an advanced engineering business or a top-quality restaurant; but they might also happen in many different locations such as dispersed building sites, anywhere robots are found, and even in people's own homes – a good example is the installation and maintenance of ground-source heat pumps, which will be done by highly-trained technicians.

Physical tasks engage the brain in ways that are both complex and subtle. Tasks done repetitively require knowledge and skill; over time, they become instinctive. However, non-routine tasks require imagination, the application of knowledge to novel or varied contexts and the ability to make judgements. Solving problems involves analysis, hypothesis, diagnosis, choosing the right tools and methods, adaptability and reflection.

This is true of non-routine, abstract tasks, too. Civil servants and political advisers also need knowledge, imagination and judgement. They, too, solve policy problems through analysis, hypothesis, diagnosis, choosing the right tools and methods, adaptability and reflection. At least, I hope they do!

Third, significantly, however, it is increasingly possible to programme computers to perform tasks which require high-level reasoning, whereas it is very hard to programme them to carry out non-routine physical tasks. Hans Moravec wrote about this as long ago as the 1980s, when he pointed out that "it is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility."[17] This is known as Moravec's Paradox.

How the nature of work will change

As machines take over more and more routine tasks, paid work of all kinds and at every level will increasingly depend on applying knowledge in novel contexts and performing non-routine tasks.

Working well with others will be a further essential requirement. To be effective, people will need to listen attentively, absorb and understand information, show empathy, speak clearly and adapt to changing moods and needs.

This is doubly important because the structure of employment is changing rapidly. According to a Bank of England analysis, around 4.5 million people – 15% of the UK workforce – are now self-employed. Growth in the rate of self-employment accounted for around a third of the increase in total employment between 2010 and 2015.[18] This trend will only continue. The other trend which is now very common is part-time working.

The working lives of self-employed and part-time workers will result from a set of skills, experience and expert knowledge traded day by day and week by week, working under contracts as short as an hour and in shifting teams. Your office will be wherever your laptop happens to be. You will experience a succession of brief encounters with clients, suppliers, temporary colleagues and collaborators, and they are likely to be your income stream. The Baker Dearing Educational Trust, like many charities, has adopted this pattern already. We employ 23 people but only 3 are full time employees; the others are headteachers, former inspectors, professional experts and business people with a training background who visit and help UTCs for anything up to 2-3 days a week.

Some call this 'portfolio working'; others, the 'gig economy'. A study in America[19] found that 4% of adults representing 13 million people are earning some income from the online platform economy, and that the rate of participating had increased 47-fold in the last three years – doubling every six months. The study, by JP Morgan Chase Institute, found that 'gig economy' workers tend to use online platforms to supplement income from a regular job. Most are young and have below average earnings in their day job. Uber drivers would be a good example of this.

The 'gig economy' is well-established in Britain and the Bank of England's Chief Economist, Andrew Haldane, paints a vision of hundreds of thousands of micro-businesses offering individually-tailored products and services, personalised to the needs of customers, from health and social care to leisure services and luxury products – all of them run by what he calls a 'new artisan class' of self-employed people.[20]

Renishaw's high-tech manufacturing facility near Cardiff.
(© Renishaw)

What we can learn from university technical colleges

The American philosopher, author and motorbike mechanic, Matthew Crawford, delivered the Edge annual lecture in 2014. He said, **"If young people are making a tube frame chassis for a racing car, suddenly trigonometry becomes very interesting – they see the point of all the measurements and calculations."**[21]

Joe Noyes, a teacher at UTC Reading, demonstrates how to fly a drone

In other words, **knowledge is as necessary as ever, but it is not enough.** Abstract knowledge and reasoning need to be connected with the real world through practical applications. A play assumes a certain meaning when read silently; more when it is read aloud; and more again when it is performed.

The same is true of maths, physics, art, music, design, technology … all come alive when used in a meaningful way.

This is the philosophy behind University Technical Colleges. Employers and teachers collaborate to design real-world projects undertaken by groups of students over a period of weeks. Each project has a direct connection with the world of work and leads to a tangible outcome such as a design, product or presentation – and often all three.

University Technical Colleges®

What we can learn...

EXAMPLES OF UTC PROJECTS

At **UTC Reading** – the UTC first to be judged outstanding by Ofsted and now oversubscribed – students worked on a project jointly devised by teachers and architects at Peter Brett Associates (PBA), with support from Network Rail. PBA challenged students to re-design the space between Reading's existing train station and a new interchange with consideration for the community, surrounding buildings, sustainability and economic viability. The project was integrated into every part of the curriculum, from English to geography and IT.

Working in mixed Year 10 and Year 12 teams and supported by PBA mentors, students carried out market research, designed their ideas using CAD (computer aided design) software and created a 3D scale model using the UTC's 3D printers. All designs and models were displayed at an exhibition that was judged by a panel from PBA.

Network Rail's involvement in the UTC project is at the heart of the rail industry strategy to tackle the engineering skills gap which the sector needs urgently to address if we are to have the world-class rail infrastructure the UK deserves.

UTCs provide a high-quality employer-led technical education, offering young people direct access to rail industry expertise, by which means we aim to inspire the next generation of engineers, technicians and business leaders with the skills to build, maintain and enhance the railway of the future. We see UTCs as the natural first step towards a rail industry Apprenticeship and the stepping-off point for a range of rewarding careers in the rail transportation sector.

Bill Templeton, *Network Rail*

Examples of UTC projects

After visiting the UTC the UK Chief Scientific Advisor, Sir Mark Walport, said:

> *"The college has an exciting ethos. It embeds stimulating practical laboratory experience in a strong science curriculum. The strong and important links to university and industry were evident as was the clear enthusiasm of the students and staff."*

At **UTC Sheffield**, students work in teams to design, test, race, review and improve model racing cars. They use computer-aided design and manufacturing on projects set by engineering businesses including Chesterfield Special Cylinders and Siemens, learn to programme robots and investigate the impact of technology on local companies such as Technophobia, Highlander and Resolve IT.

At **Liverpool Life Sciences UTC**, students have carried out projects to investigate malaria, retroviruses, cancer and ageing, supported by local employers – including the NHS – and the University of Liverpool. From the day the UTC opened, genetics have featured strongly: students investigate the genome of an organism, and use computer science to compare the primary biological sequence information of each genome such as its nucleotides – the molecules that serve as the building blocks of DNA. More recently, an industry partner, Croda, devised a student project to establish whether genes from photosynthesising cyanobacteria could be isolated and captured for production.

Employers are involved in the design of projects across all UTCs. They also offer master classes, workshops, visits, work experience, sponsorship and mentoring. These opportunities allow students to develop employability skills such as problem-solving, time management, planning, team working, leadership and communication skills.

UTCs came into being because employers said conventional schools and colleges were failing to equip young people with the breadth of skills, knowledge and personal attributes they look for in new recruits.

Left: *UTC Reading students were set the task of re-designing the space between the new station and the rail interchange*

Above: *A UTC student making mechanical parts on a 3D printer*

Right: *Students at Liverpool Life Sciences UTC learning how to keep neuroblastoma cultures alive*

*Left: **Robots at UTC Sheffield***

Ron Dearing and I were convinced that the solution lay in a new curriculum, blending traditional academic subjects with technical specialisms and project-based learning. Close ties to universities and employers ensure that students see the relevance of what they are learning: thanks to employers, learning becomes *authentic*.

UTC students leave with qualifications and go on to apprenticeships, further and higher education and careers. Our ambition is that no UTC student joins the NEET register when they leave – not in education, employment or training. Our target is 100%. In July 2015 we had 2,000 leavers: at 16, 99.5% stayed in education, started an apprenticeship or got a job, and at 18, 97% went into further learning or work.

Success means more than a set of exams in a league table. In addition to a good grounding in core academic subjects – English, maths, science and so on – work-ready students at UTCs have:

- Reasoning skills
- The ability to examine and solve problems
- Experience of working in teams
- An ability to make data-based decisions – they are 'data savvy'
- Social skills – particularly the confidence to talk to and work with adults from outside school
- The skills of critical thinking, active listening, presentation and persuasion
- Practical skills: the ability to make and do things for real
- Basic business knowledge

University Technical Colleges are among very few institutions in our education system which set out to develop these skills. We ought to establish as many as possible as soon as possible.

UTC students – 2015 destinations

We are training technicians, engineers and scientists. Our target is no NEETs

At 16

1,181 students left UTCs

99.5%

of students stayed in education, started an apprenticeship, or started a job

At 18

700 students left 14 UTCs

97%

of students stayed in education, started an apprenticeship, or started a job

42%

OF UTC LEAVERS WENT TO UNIVERSITY

Compared with 37% nationally

24%

OF UTC LEAVERS STARTED APPRENTICESHIPS

Compared with 8.5% nationally

UTCs

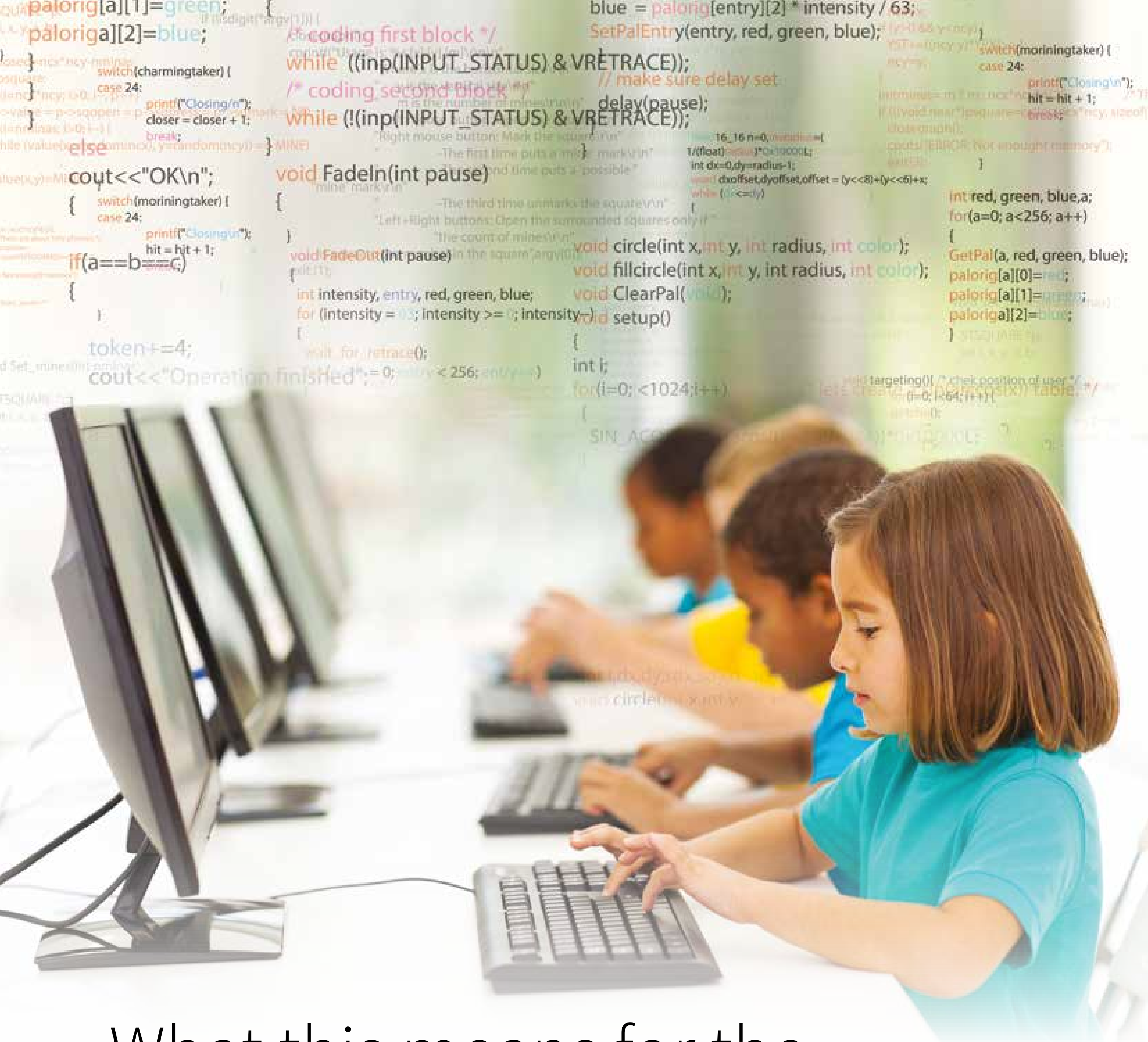
29 UTCs open
55+ by 2017
35,000 places by 2017

Specialisms

Engineering
Cyber security
Health sciences
Manufacturing
Digital technologies
Built environment

Backed by

50 universities
600 employers



What this means for the education system as a whole

In the Digital Revolution all our young people need a broad range of skills, attitudes and experiences, not just those fortunate to attend a UTC. Yet this thinking is entirely absent from the core curriculum in mainstream schools.

Part of the problem is that we associate open-ended possibilities only with a general education. The basic assumption is that a knowledge-based curriculum keeps options open, while a technical curriculum narrows them. This is simply not true. UTC students can choose an apprenticeship or degree in a vast range of subjects and careers. In fact, their range of choice is enhanced, precisely because they leave with the skills and attributes listed earlier.

What this means for the education system as a whole

There is also a bias against practical and technical subjects. Design and Technology, for example, is being squeezed out of schools at GCSE and A-Level. Over the last five years, GCSE entries have fallen by nearly 20%, and A level by nearly 30%.

The Government's White Paper has a firm commitment for students to focus on 7 academic subjects at GCSE - English language, English literature, maths, two sciences, a modern or ancient language, geography or history, plus probably a third science. This is word-for-word the curriculum laid down by the Education Act of 1904, though it added three subjects - drawing, cooking for girls, and carpentry or metalwork for boys.

We should not go back to a 19th century diet of academic subjects for all. All young people should make and do things as part of a broad and balanced curriculum. The technical work in Design and Technology on resistant materials, product design and graphic art are all needed for a variety of jobs from industrial simulations to video gaming. It also stimulates creativity.

The nature of *making* and *doing* must, of course, keep pace with the technological revolution: every primary school should have 3D printers, and computer science should be as common in schools as modern foreign languages because programming skills will be vital for many people in the future. Earlier, I gave the example of Sir Charlie Mayfield and the John Lewis Partnership, but computer science is as important to Amazon and the NHS as it is to self-employed app designers. Computational thinking is a useful skill in itself that can be applied in many contexts, whether or not students go on to write apps and computer programs.

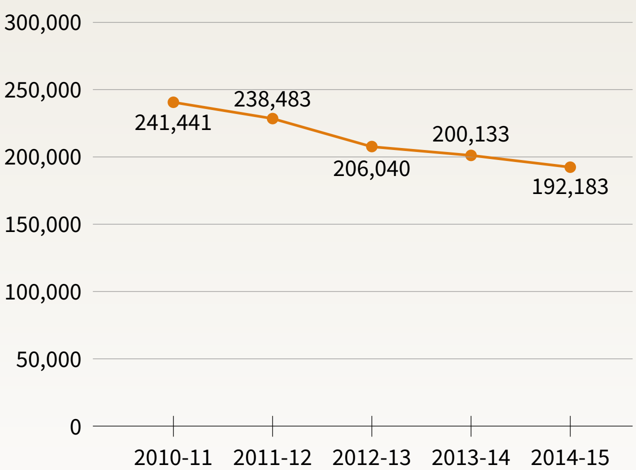
Furthermore, students who study Computer Science and Design & Technology at GCSE would be capable of doing an advanced apprenticeship at 16, whereas students who just take academic subjects up to 16 would find it difficult to find a company willing to take them on as apprentices – perhaps not even at level 2, intermediate level apprenticeships.

More broadly, we must not neglect students' social skills. As Andrew Haldane of the Bank of England explains:

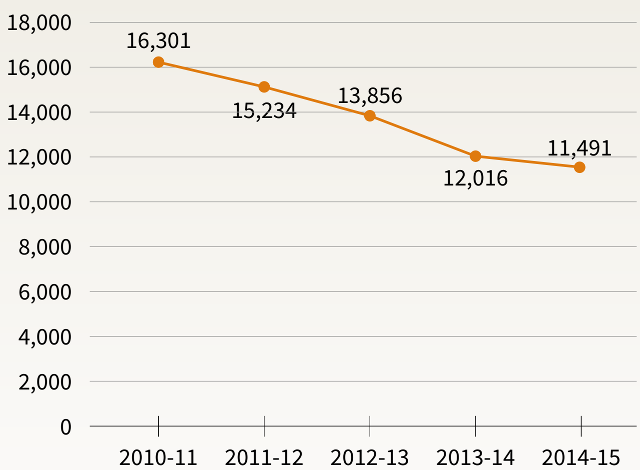
> *In a world in which machines came to dominate tasks involving core cognitive processing, the importance of, and skill premium attached to, non-cognitive skills is likely to rise. The high skill/high pay jobs of the future may involve skills better measured by EQs than IQs[22], by jobs creating social as much as financial value. Yet our education system, at present, has a strongly cognitive slant. Perhaps in future that will need to change, with as much effort put into cultivating social CVs as academic ones.*[23]

Links with employers are vitally important. We must ensure that all young people, in all types of school, encounter people from many walks of life throughout their time in education, from primary education onwards,

Design and Technology GCSE entries (England)



Design and Technology A level entries (England)



Source (both graphs): The Joint Council for Qualifications partly so they gain a full appreciation of the myriad career opportunities that lie ahead, partly to become accustomed to talking to adults from outside school, and partly so they can see how things learned in the classroom apply in the world of work.

We have to get this right. For one thing, we have to keep in mind Moravec's Paradox: it is harder for machines to carry out non-routine physical tasks than to perform high-level reasoning.

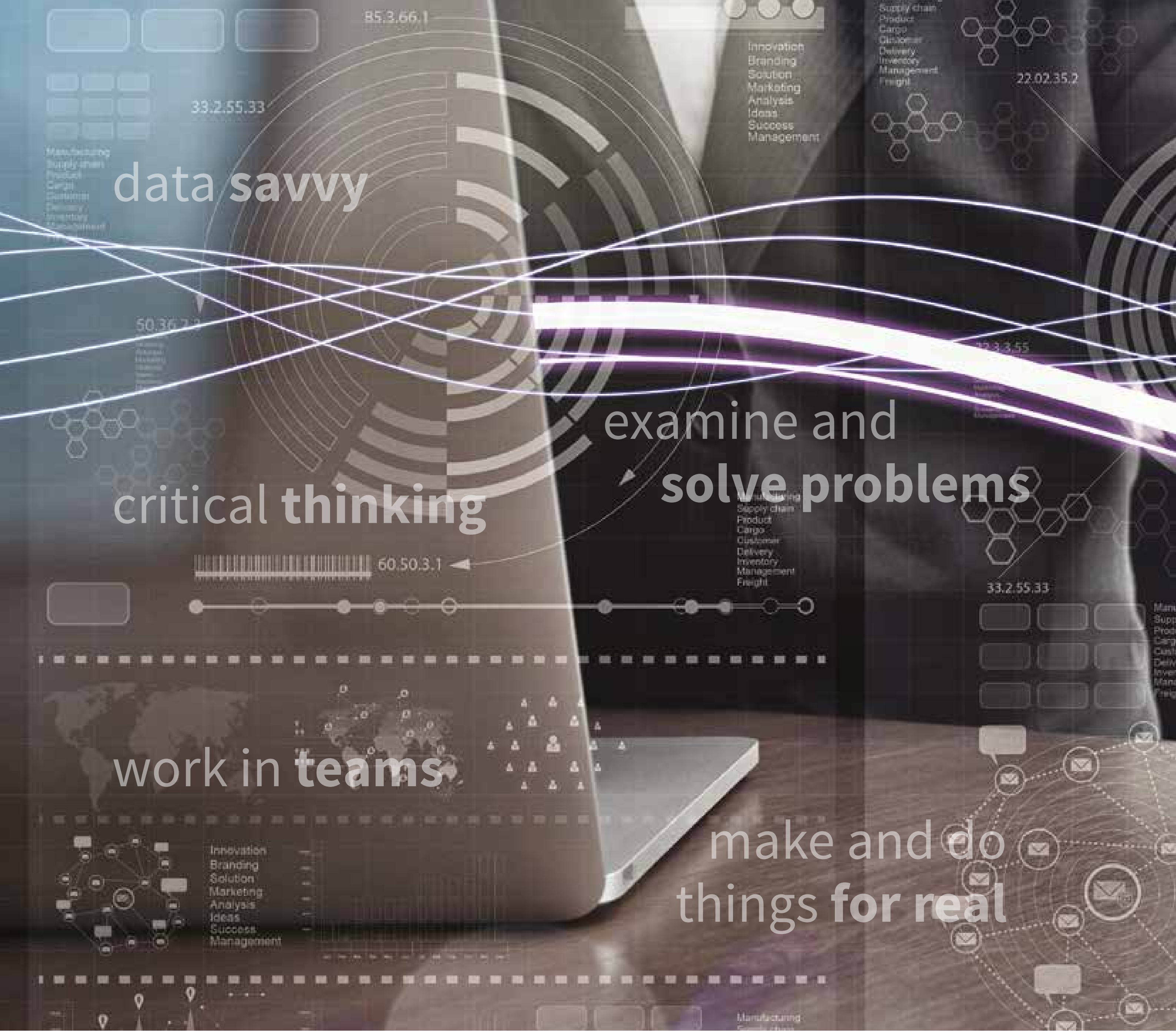
Applying this logic, Erik Brynjolfsson and Andrew McAfee point out that "cooks, gardeners, repairmen, carpenters, dentists, and home health aides are not about to be replaced by machines in the short term. All of these professions involve a lot of sensorimotor work, and many of them also require the skills of ideation, large-frame pattern recognition, and complex communication".[24]

Yet while many jobs will be safe from the Digital Revolution – for now, at least – millions of others are at risk. We have to prepare young people for jobs that do not exist yet, and for flexible ways of working that would astound Henry Ford. Again, this means looking afresh at our school curriculum and building in the right mix of knowledge, skills, practice and teamwork so that young people are ready for whatever the Fourth Industrial Revolution throws their way. We must make sure that all young people leave school with qualifications, yes; but also the full range of skills, experience and personal attributes developed by UTCs.

"We can trace some of today's misunderstandings to the separation of thinking and doing on assembly lines. The first motorcars were built by people recruited from cycle manufacturers. They were masters of their craft. The point of Henry Ford's assembly line was to separate the conception of the work from its execution. This coincided with the concept of scientific management, which sought to treat the human body as a machine. The aim was to see how far you could push the speed and efficiency of production. This was overseen by a separate management class.

Partly because of this separation of thinking and doing, there was an 'officer class' responsible for the conception of how things should be done by workers who, for their part, remain largely ignorant of the thought processes that led to those decisions."

Matthew Crawford: transcript of Edge Annual Lecture, 2014



A new programme for education

1. Primary schools now have to teach coding but many of their teachers will have no experience of this. They should be encouraged to bring in outside experts. There are many educational apps and robots which teach basic coding skills and sell at prices which are falling constantly.

2. Primary schools should also have 3D printers and the design software that drives them. Children will take to them very quickly. The 1981 programme to get one computer into every school, launched by Margaret Thatcher personally, offered a discount of 50% on one of two computers. A similar programme could be launched.

3. Secondary schools should aim to provide the Computer Science GCSE for at least half of all 16 year olds.

4. Secondary schools should be able to substitute for the foreign language GCSE at 16 a GCSE in Computer Science or Design and Technology, or another technical/practical subject. To master a computer language will be more useful in the workplace than a smattering of a foreign language. English is the language of the new technological age.

5. We should reintroduce young apprenticeships at 14, enabling young people to start an apprenticeship alongside the core curriculum even before the age of 16.

Many of the great inventors of the First Industrial Revolution, including James Watt, Josiah Wedgwood and Michael Faraday, started as apprentices at 14.

6. All students should learn about how businesses work – marketing, sales, design, customer services, budgetary control, cash flow, profit and loss, partnerships and companies. They should be encouraged to be enterprising and entrepreneurial both for the people they work for and on their own account. This will allow students, if they wish, to convert their expertise, knowledge, skills and ideas into an income stream from an early age.

7. Schools should be encouraged to develop a technical stream from 14-18 for some of their students covering enterprise, health, design and hands-on skills, for example robotics, electronics, material engineering and other strands of the modern Design and Technology curriculum. This would develop into a pathway of success different from the normal route of '3 A-Levels and University', leading to degree apprenticeships.

8. Universities should provide part-time courses for apprentices to get Foundation and Honours degrees. A degree apprentice should have no student debt.

Notes

1. McLeod S and Fisch K, quoted in World Economic Forum (2016), The Future of Jobs

2. "Nearly 300,000 civilian drones registered in US in 30 days", the Guardian, 26 January 2016 *www.theguardian.com/technology/2016/jan/26/300000-civilian-drones-registered-in-us-compulsory*

3. Leslie Hook, "Venture capital starts to tune out of on-demand services", *Financial Times*, 24 February 2016

4. Ford M (2015), *Rise of the Robots: Technology and the Threat of a Jobless Future.* New York: Basic Books

5. Nesta Policy Briefing, July 2015, Analytic Britain: Securing the Right Skills for the Data-Driven Economy

6. Source: *www.alltrucking.com/faq/truck-drivers-in-the-usa/*

7. Mark Fields, quoted in "Self-driving cars hog the road at CES" by Nellie Bowles and Danny Yadron, T*he Guardian,* 7 January 2016

8. Clive Thompson, "Uber would like to buy your robotics department", New York Times, 11 September 2015 *www.nytimes.com/2015/09/13/magazine/uber-would-like-to-buy-your-robotics-department.html?_r=0*

9. Frey C B and Osborne M A (2013), The Future of Employment: How susceptible are jobs to computerisation? *www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf*

10. Speech by Andrew G Haldane, Chief Economist, Bank of England, 12 November 2015 *www.bankofengland.co.uk/publications/Documents/speeches/2015/speech864.pdf*

11. Manyika J, Chui M, Bughin J, Dobbs R, Bisson P and Marrs R (2014), Disruptive technologies: Advances that will transform life, business, and the global economy

12. World Economic Forum (2016), *The Future of Jobs*

13. Retail 2020: fewer but better jobs. British Retail Consortium, February 2016.

14. Source: Office for National Statistics, Public Sector Employment, Q1 2015.

15. I wrote about this in an earlier Edge report, "The Skills Mismatch" (2014): *www.edge.co.uk/media/130721/the_skills_mismatch_march_2014_final.pdf*

16. Data derived from "What Do Graduates Do?", Prospects/AGCAS, 2015

17. Moravec H (1988), *Mind Children: the future of robot and human intelligence*. Harvard University Press

18. Tatomir S, "Self-employment: what can we learn from recent developments?" in Bank of England Quarterly Bulletin 2015 Q1

19. Farrell D and Greig F (2016), Paychecks, Paydays, and the Online Platform Economy. JP Morgan Chase Institute.

20. Speech by Andrew G Haldane, 12 November 2015

21. From a transcript of the Edge Annual Lecture, October 2014.

22. IQ: Intelligence Quotient. EQ: Emotional intelligence Quotient

23. Speech by Andrew Haldane, 12 November 2015

24. Brynjolfsson E and McAfee A (2014), *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies.* W W Norton & Company

About the author:
The Rt Hon Lord Baker of Dorking CH

Kenneth Baker was a Conservative MP from 1968-1997.

He was the first Minister for Information Technology and was responsible for introducing computers into schools; Local Government Minister; Environment Secretary; Secretary of State for Education and Science, introducing the National Curriculum, Grant Maintained Schools, City Technology Colleges and student loans; and Home Secretary. He left the Government after the 1992 election, was appointed a Companion of Honour, and became a member of the House of Lords in 1997.

Lord Baker is Chairman of the Edge Foundation, an educational charity championing technical, practical and professional learning. He is also Chairman of the Baker Dearing Educational Trust, which is spearheading the development of University Technical Colleges. He is the author of several books, including '14-18: A New Vision for Secondary Education', which was published by Bloomsbury in 2013.

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