SKILLS AND EDUCATION FOR ROBOTICS AND AI (SERAI)

A report for SHEFFIELD ROBOTICS

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With support from the University of Sheffield Knowledge Exchange (KE) Programme.
PART 1 - THE ISSUE

p7 INTRODUCTION - An outline of the many opportunities that Industry 4.0 offers the UK in terms of productivity, potential national prosperity and progressive social and economic change. The introduction also offers a comparison between Industry 4.0 and the industrial revolutions preceding it and provides a summary and review of current literature.

p8 SKILLS - An analysis of the range of skills that will be required if the UK is to take advantage of the opportunities that Industry 4.0 provides, in light of the maxim that industrial revolutions represent ‘a race between education and technology’. Although commentators agree that skills and education are key to success in Industry 4.0, analysts and business leaders conclude that Britain is starting to fall behind many of its industrial competitors in terms of basic skills and STEM education.

p10 COMPUTER SCIENCE EDUCATION - As the influential report by the Royal Society last year testified, there is a crisis in computing education in schools, which allied to a STEM skills deficit, is hampering the UK in taking advantage of the opportunities presented by Industry 4.0. A damning statistic from the report, that 44% of computer science teachers do not feel confident in teaching the computing segments of the GCSE, is partly explained by a lack of effective continuing professional development (CPD) for teachers, as is the lack of robotics and AI in the curriculum.

p11 GENDER - The UK’s low ranking in STEM skills is not helped by a chronic gender imbalance in technology and engineering. Britain has the lowest ratio of women working in engineering in Europe. Although girls outperform boys in STEM GCSEs and A levels, less than a quarter of people working in STEM are female. A lack of female role models is cited as a major cause for the gender discrepancy as is a lack of female STEM teachers in secondary schools.

p13 ADULT SKILLS TRAINING - Reskilling the adult workforce to work alongside the new technologies employed in Industry 4.0 is just as important as improving STEM education at school level. The Made Smarter Review estimates that two million people in the workplace will need to upskill or reskill to satisfy industry’s demand in the short to medium term, especially in light of the fact that 99.4% of businesses in the UK are SMEs.

p14 FURTHER EDUCATION - With neither schools nor private-sector business able to provide the requisite skills training, we ask whether Further Education is able to make up the shortfall. Spending cuts have decimated HE, however, leading HEFQ to call for a new multi-stakeholder approach to adult skills training.

p15 ROBOTS AND FUTURE EMPLOYMENT - ‘Robots and AI will take our jobs then kill us all’ according to many newspaper headlines and TV reports on the rise of R&AI. Such a dystopia may never come to pass, however, with the evidence of past industrial revolutions suggesting that new technology generally creates rather than reduces employment and prosperity.

p16 ROBOTICS AND FUTURE EMPLOYMENT - Collaborative robotics offer a more positive alternative vision of the future in which workers operate alongside robots, maximising the abilities of both humans and machines to help the UK thrive in the agile environment of Industry 4.0. Dr Law, of Sheffield Robotics, envisages a Factory of the Future that manufactures smaller batches of a wider variety of products more tailored to customers’ needs and calls for a skill development program to enable the UK to compete in R&AI manufacturing.

PART 2 - OVERVIEW OF CURRENT SKILLS INITIATIVES

This section will examine some skills initiatives at Sheffield University and in the city and beyond and explore what key stakeholders at the university see as their role in upskilling the British workforce in readiness of Industry 4.0.

p19 COLLABORATIVE ROBOTICS AND SKILLS AT SHEFFIELD UNIVERSITY - An interview with Dr Iveta Eimontaite, who describes her work with Dr Law on technology acceptance and managing the public’s negative attitudes towards robotics. Dr Eimontate concludes that public engagement is key to technology acceptance and that by meeting and interacting with robots and AI, industrial workers are far more likely to embrace them.

p20 INTERVIEW WITH DR GWENDOLEN REILLY - As Faculty Director of Women in Engineering at Sheffield University, Dr Reilly discusses methods to address the gender imbalance in STEM education and engineering careers. She believes that gender stereotyping and a dearth of female role models in science and engineering are major factors leading to the gender split. Having witnessed the
damaging negative press to bioengineering a decade ago, Dr Reilly believes that public engagement and positive publicity are the best ways to address the current negative public perception of robotics and AI.

INTERVIEW WITH PROFESSOR JACKIE MARSH - Professor of Education at Sheffield University, Jackie Marsh specialises in the digital education of pre-school children and relates that Britain’s STEM skills deficit has its origins early in people’s lives. She advocates the use of play, art and other informal pedagogical approaches to interest young children in technology and inspire them into a future STEM career. Working with Makers to engage children and the wider community is an approach to outreach and public engagement that Professor Marsh feels has great potential, especially in teaching the more integrated, adaptable knowledge and skillset required in future industry.

INTERVIEW WITH CATHERINE ELLIOTT - eLearning consultant with Sheffield City Council, Catherine Elliott has extensive experience in digital literacy and like Professor Marsh is an exponent of Making as a method to engage children in STEM. Her NESTA-funded Make:Learn:Share project, a citywide ‘Made in Sheffield’ Young Ambassadors program, has trained over 100 secondary school students to deliver technology workshops to primary school children.

INTERVIEW WITH HOWARD BAKER - Creator of the Micrco:bit and instigator of the ‘million drop’ whereby a million Micro:bit computers were given free to pupils starting secondary school, Mr Baker has widespread experience in Making and widespread public engagement programs. Like Professor Marsh and Catherine Elliott, he holds informal, open-ended learning to be key to developing adaptive knowledge and skillsets and thinks that a nationwide project around Making and robotics could have a big part to play in STEM public engagement and CPD.

INTERVIEW WITH SEB ROSE - Software developer, author and analyst Seb Rose relates his experiences in Making, with the First Lego League and coding clubs in Scotland, arguing that it is not just coding skills that the future workforce will need, but a solid grounding in STEM and an agile, adaptable skill set.

INTERVIEW WITH DAVE GIBBS - Mr Gibbs is a computing and technology specialist for STEM Learning. He discusses initiatives to raise STEM skill levels that he has been involved in such as the STEM Ambassadors program and the Little Big Futures Project, to encourage girls into STEM and develop open-ended problem-solving STEM skills training. Mr Gibbs believes that entry-level robotics can have a big part to play in STEM public engagement and CPD.

PART 3 – CONCLUSIONS & RECOMMENDATIONS

CONCLUSION - Having reviewed the experiences, ideas and initiatives of the interviewees who contributed to the report, as well as the literature surveyed in Part One, the SERAI report concludes that universities could have a major role to play in helping to provide the requisite skills training, curriculum development, outreach and effective public engagement that is needed to produce a workforce sufficiently skilled and accepting of robotics and AI to help the UK thrive in Industry 4.0.

RECOMMENDATIONS - This report recommends that Sheffield Robotics establishes a sustainable programme of public engagement and outreach services, hands-on skills training, curriculum development and CPD in robotics and artificial intelligence in line with the UK government’s new Local Industrial Strategy and Digital Skills Partnerships program and building on the success of Sheffield and the AMRC as the UK’s first digital innovation hub. Such an initiative could be supported by grants, licensing, consultancy and training fees, and fees for robot demonstrations and exhibits for for-profit organisations and that it could establish Sheffield as the initial hub of a UK-wide network of “Robot Maker Centres” and mobile “Robot Maker Units” that could significantly impact on national skills and education in robotics and AI.

REFERENCES

J.M.Keynes: “The reason why human labour has prevailed relates to its ability to adopt and acquire new skills by means of education”.

Marie Curie: “Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less”.

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Part 1

THE ISSUE

Introduction

“We are at one of the most important, exciting and challenging times in the history of global enterprise”, according to Secretary of State for Business, Energy and Industrial Strategy, The Rt Honourable Greg Clark, in the opening words of his recent Industrial Strategy White Paper Building a Britain Fit for the Future. What enables the exciting industrial and commercial future that the White Paper anticipates are technologies such as robotics and AI that are currently revolutionising the global economy and society. Britain, the Secretary of State goes on to say, ‘is extraordinarily well-placed to benefit from this new industrial revolution’ and that “the earliest adopters of new technologies are able to reap the greatest rewards in terms of additional jobs and increased revenue”.

The industrial revolution that he cites has become widely known as Industry 4.0, or the fourth Industrial Revolution; the former three being those powered by steam, electricity and computing. Originally coined by the economist and engineer Klaus Schwab, the fourth industrial revolution is characterised by a blurring of the physical and technological worlds, powered as it is by robotics, AI, the Internet of Things, cloud computing and additive manufacturing. Furthermore, as Siemens CEO Professor Juergen Maier highlights in the Made Smarter Review, although ‘emergent technology breakthroughs in fields such as AI, robotics, and the Internet of Things are significant in their own right … it is the convergence of these IDTs that really turbo-charges their impact’. As with the previous industrial revolutions, the influence of such a powerful congruence of new technologies on industry, society and the economy are both hugely disruptive and potentially highly progressive.

The analogous linking of Industry 4.0 with the previous three industrial revolutions that shaped, disrupted and developed the world’s economy and society over the last two hundred and fifty years, is far from specious. As George Gersetz and Guy Michaels reported in their 2015 paper Robots at Work for the CEP, robot densification across the major industrialised nations between 1993 and 2007 raised GDP and labour productivity by 0.37 and 0.36% respectively, a figure “fairly comparable to the estimated total contribution of steam technology to British annual labour productivity growth”.

According to the 2016 Citi GPS report with the Oxford Martin School, over 96% of institutional clients who participated in Citi’s survey on technology and work ‘believe that automation will accelerate over the next five years relative to the previous five years’. As director of the Oxford Martin School, Ian Goldin, and Citi’s Global Head of Research Andrew Pitt, comment in their foreword to the report such ‘technological dynamism will remain the best way to maximise employment and to benefit positively from new technologies’. To attempt to assign some figures to the potential benefits of answering the Secretary of State’s call for early adoption of the new technologies powering Industry 4.0, “the work undertaken for the Made Smarter Review found that the positive impact of faster innovation and adoption of IDTs could be as much as £455 billion for UK manufacturing over the next decade, increasing manufacturing sector growth between 1.5 and 3 percent per annum, creating a conservative estimated net gain of 175,000 jobs throughout the economy.” Overall, from the data and evidence collated, we are confident that industrial productivity can be improved by more than 25 percent by 2025.

In October 2017, Fellow of the Royal Society Professor Dame Wendy Hall and the VP of AI at Facebook Jerome Pesenti published their much-anticipated review into how to grow the Artificial Intelligence industry in the UK, the country where Alan Turing is widely anticipated as having launched and inspired much of the development of AI just after the Second World War. The authors opened their executive summary with the promise that ‘increased use of Artificial Intelligence (AI) can bring major social and economic benefits to the UK. With AI, computers can analyse and learn from information at higher accuracy and speed than humans can. AI offers massive gains in efficiency and performance to most or all industry sectors, from drug discovery to logistics. AI is software that can be integrated into existing processes, improving them, scaling them, and reducing their costs, by making or suggesting more accurate decisions through better use of information. It has been estimated that AI could add an additional USD $814 billion (£630bn) to the UK economy by 2025, increasing the annual growth rate of GVA from 2.5 to 3.9%.” Our vision is for the UK to become the best place in the world for businesses developing and deploying AI to start, grow and thrive, and to realise all the benefits the technology offers.”

In the words of the Secretary of State for Business: “to benefit from the opportunities before us, we need to prepare to seize them.” The Secretary of State develops the argument further, stating that “as with previous revolutionary technologies, these changes cannot be resisted and it would be
irresponsible to fail to prepare. Meeting our Grand Challenge means maximising the opportunities created by AI and advanced data technologies and responding to the potential impacts on society. CBI President, Dame Carolyn Fairbairn, recently wrote, ‘we need to enable all potential and have left too many of the opportunities arising from the Third Industrial Revolution to other nations.’

Skills

The key to enabling the UK to seize and maximise the opportunities generated by the Fourth Industrial Revolution is having a director-general of the CBI, Carolyn Fairbairn, recently wrote, is skills training and education. ‘Investing in all our skills is at the heart of building an economy that is fit for the future. Skills are vital to competing globally – and seizing the opportunities of the Fourth Industrial Revolution.’

As Goldin and Katz observed of the industrial revolutions of the twentieth century – that it was a ‘race between education and technology’ - so the Fourth Industrial Revolution of the twenty-first century ‘will have extraordinary implications on the range of skills that today’s young people will require in every aspect of their lives’ since ‘digitisation means that around two-thirds of children in primary school today will work in jobs which do not even exist yet. The nature of employment is also continuing to change. The days of working for a single employer have ended. Individuals will have a number of careers over their working lives and will need to continually reskill to be relevant in the marketplace. There is a need to develop a culture of lifelong learning and reskilling, such as the Singapore “skills future program”.

How alarming then that a survey by the UK charity GoOn.UK, and cited in the Made Smarter Review, recently found that in Britain over 23 million people and a million small and medium-sized businesses do not have the skills to prosper in the digital era. The UK currently ranks just 18th in the world in ‘skill levels’ – success or failure to thrive in Industry 4.0 according to a recent UBS White Paper for the World Economic Forum held behind Singapore, Finland, the Netherlands, Switzerland, Belgium, the US, Norway, Australia, Denmark, New Zealand, Sweden, Hong Kong, Taiwan, Ireland, Austria, and Germany; the vast majority of our major industrial competitors. Britain is only 12th in the same study on education allows adaptive skills’, in other words the education system produces workers who can adapt to the kind of rapidly evolving technologies and working practices inherent in Industry 4.0.

Britain performs well at the highest academic and professional levels – with three universities in the top ten for STEM according to higher education advisor Quacquarelli Symonds (QS) and sixth in the world in the Scientific American’s scorecard of ‘Best Countries in Science’, but it is mainly the low levels of more basic STEM skills in the wider population that account for its position below most of its competitors in terms of skills leading to a country thriving in industry 4.0.

The British Academy cites a Tech Partnership Committee Inquiry into Robotics and Artificial Intelligence, a representative of vanguard AI think tank DeepMind stated that ‘one of the most important steps we must take is ensuring there are enough trained and qualified AI professionals to meet demand’. The future workforce will be skilled to become ‘digital workers’ and ‘digital makers’.

‘Yet, there are 10.5 million people currently lacking basic online skills, the majority of whom are aged over 55, and many of whom are working in sectors where digitalisation will be crucial to keep the UK competitive internationally. The pace of change unleashed by digitalisation means that around two-thirds of children in primary school today will work in jobs which do not even exist yet. The nature of employment is also continuing to change. The days of working for a single employer have ended. Individuals will have a number of careers over their working lives and will need to continually reskill to be relevant in the marketplace. There is a need to develop a culture of lifelong learning and reskilling, such as the Singapore “skills future program”.

As Professor Dame Wendy Hall and Jérôme Pesenti point out in their influential paper ‘Making AI in the UK: the more people who have the right foundational STEM skills, the more can train in the higher skills, but also more will be able to work in adjacent roles: working in and around AI rather than developing it at the most complex levels’.

So it is not just high-level skills – the skills to build and design the robots of make similarly gloomy reading: ‘there is already an identified shortage of digital skills in the UK economy, and the demand for these skills is projected to increase. It has been predicted that, within 20 years, 98 percent of all jobs will require digital skills. This means that approximately 16.5 million people in the UK are going to need to be skilled to become “digital workers” and “digital makers”.

Skilled and educated workers are key to ensuring that businesses do not have the skills to prosper in the digital era.'
the future and code and program AI and new forms of Machine Learning – but a wider range of STEM skills, basic competencies in the sciences, technology and mathematics that can serve as a bedrock of knowledge on which to build these skills of the future and the more creative, problem-solving skills that workers of the future will need when working with intelligent machines if the UK is to truly thrive in Industry 4.0.

In its response to the initial government green paper Building Our Industrial Strategy, the authors of Nesta’s paper highlight the remarkable statistic of ‘one popular estimate that 65 per cent of children entering primary school in 2016 will by the time they are economically active (in 15 or so years) work in completely new jobs that do not exist today’. All the more important that we set learning priorities for young people today that are grounded in what will be needed of them when they enter the workforce.30

As Professor Hall and Jérôme Pesenti put it: ‘the add-on of computer science to the National Curriculum is an excellent step but will only deliver fully if there are enough teachers who can teach it well. The British Computer Society, who have recently suggested that 70% of students are taking up computer science and suggested that as many as 78% of secondary school computer science teachers could be lacking a relevant computer science background to teach at GCSE level. Therefore, more and better teacher training in computer science would improve outcomes.’ In a survey especially commissioned for the report, the Royal Society found that 64% of secondary school teachers only felt confident teaching the earlier stages of the curriculum whereas there is less of a computer science focus. Not only that but 20% of the secondary school teachers we surveyed indicated that they had not undertaken any computing-related professional development activities in the past year, giving them little chance to gain the confidence in teaching computing that many lack. The problem is exacerbated by the fact that schools are finding it increasingly difficult to attract new teachers to computing, with England meeting only 80% of its recruitment target from 2012 to 2017.

Dave Gibbs, the Computing and Technology Specialist for STEM Learning UK, feels that ‘the main reason that barely half of the computing components of the GCSE course are delivered and its assessment is focused on achievement rather than progress’. He suggests that ‘many teachers now teaching computing are not educated in the computing background, and so find the content of the GCSE course hard to comprehend, let alone teaching able to teach pupils taking the course’. Gibbs adds, ‘the Royal Society feel comfortable teaching the computing components of the curriculum which there is less of a computer science focus.’ Not only that but 50% of the secondary school teachers we surveyed indicated that they had not undertaken any computing-related professional development activities in the past year, giving them little chance to gain the confidence in teaching computing that many lack. The problem is exacerbated by the fact that schools are finding it increasingly difficult to attract new teachers to computing, with England meeting only 80% of its recruitment target from 2012 to 2017.

A paper on requisite digital skills for the UK economy by Ecorys UK advises the government that ‘there will be a need for professionals who can use AI tools successfully in specific domain areas, including: research scientists, maintenance technicians, surgical technicians and all those professionals working with assistive technology, mechanical and electrical engineers, transport drivers, and “aplying AI” roles in service sectors – insurance, advertising, design, creative, retail, entertainment’. There have been several reports in recent years that developed and evidenced the case for improving education and training in maths, computing, data science, and the full range of digital skills.29

Computer Science Education

The Royal Society opens its highly influential 2017 report After the Reboot – Computing Education in UK Schools by similarly identifying evolutionary transformatonal changes that the ‘unprecedented digital revolution’ is bringing with it: ‘a transformation of education, society and the nature of life;’ stressing that ‘it will have extraordinary implications on the range of skills that today’s young people will require in every aspect of their lives.’

The Royal Society’s report follows the calls of academia and industry cited above concerning skills for AI in the UK that the computing education must enable young students to continue to keep up with the pace of technological change. The Royal Society report suggests that education of the future generations and our economic prosperity as a nation.29 What the Royal Society found, however, was that ‘computing education across the UK is patchy and fragile’, with insufficient time given to computing lessons in the curriculum. ‘A majority of teachers … teaching an unfamiliar subject without adequate support.’30 In a survey especially commissioned for the report, the Royal Society found that 64% of secondary school teachers only felt confident teaching the earlier stages of the curriculum where there is less of a computer science focus. Not only that but 20% of the secondary school teachers we surveyed indicated that they had not undertaken any computing-related professional development activities in the past year, giving them little chance to gain the confidence in teaching computing that many lack. The problem is exacerbated by the fact that schools are finding it increasingly difficult to attract new teachers to computing, with England meeting only 80% of its recruitment target from 2012 to 2017.

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science and technology isn’t for them. If they are determined enough, Dr Reilly feels, to pursue a STEM education and career, ‘they are often in a minority and are easily singled out, so that teachers and lecturers may not be treating them the same as men without even realising it. When they apply for jobs, it’s the same thing; they might be the only woman applying – then they feel discriminated against or singled out again. It goes on and on.’ So much so that the UK has the lowest percentage of female engineering professionals in Europe, at less than 10%, while Latvia, Bulgaria and Cyprus, for example, lead with nearly 30%.

Citing the Institute of Engineering and Technology’s 2015 survey into gender ratios in engineering and technology, The Women’s Budget Group’s response to the BEIS Green Paper points out that ‘some of the statistics highlighted in the IET’s report have not changed significantly since 2005... For example, the number of women in engineering has remained under 18 per cent of the total engineering workforce in the UK; the gender balance in the profession remains one of the worst in Europe.’ The Group has some strong advice for the UK government: ‘The continued issues of low productivity in the UK economy demonstrate the need for investment in education and training and we welcome the opportunity to update existing skills or reskill the current adult workforce as well as concentrating on improving STEM education at school level: “Lifelong learning will also be important in a changing work environment and improvements in further education will be required to support an industrial strategy in which economic growth and support for working communities dovetail effectively with changing industrial practises linked to (for example) automation.”’

Professor Julie Lydon, Chair of Universities Wales, makes a similar point in her paper The Robots are Coming: “as well as providing education and training to young people just entering the labour market, it will become increasingly important to ensure that those already in the workforce are given the opportunity to upskill and reskill as the economy and the workplace enters a period of predicted rapid change.”

As the authors of the Made Smarter Review point out: ‘because around two-thirds of the workforce of 2030 has already left the education system, the UK cannot rely on the education system to satisfy industry’s demand for digital skills in the short to medium term; this means that two million people will potentially need to be upskilled or reskilled in the workplace.’

Again, the UK Women’s Budget Group offered strong advice to the Department of BEIS in its response to the Building our Industrial Strategy Green Paper: ‘successive governments have failed to develop a training culture that accepts that high productivity and the good employment conditions required to produce it both need the development of skills, both by the state and by encouraging/requiring employers to train. This is not a sensible strategy for a relatively rich country such as the UK. It has led to British workers being less productive, paid less well and treated worse than those of currently much poorer countries.’

Perhaps the UK Women’s Budget Group’s admonition was taken on board by the writers of the resultant Building a Britain Fit for the Future White Paper with the pledge that “as technological change transforms the jobs and the skills that our businesses require, we need to make sure that people have the opportunity to learn and train throughout their working lives. At the moment, our problem is not unemployment caused by technology; it is low earning power caused by, among other reasons, a failure to use technology. Through our Industrial Strategy, we are determined to ensure that we have both the skills to take advantage of new technologies and the means to help those who are affected by technological change.”

The authors of the Made Smarter Review certainly concur with the need to provide businesses with the requisite skills for them to flourish in Industry 4.0 but would concentrate their efforts on SMEs since ‘99.4 percent of UK companies are SMEs, with limited capacity and capability to adopt digital technology. Industrial SMEs frequently lack the information, expertise and skills, training, resources, strategy and, moreover, the confidence to adopt new technologies.'

Adult Skills Training

The Royal Society also stresses the need to reskill the current adult workforce as well as concentrating on improving STEM education at school level: “Lifelong learning will also be important in a changing work environment and improvements in further education will be required to support an industrial strategy in which economic growth and support for working communities dovetail effectively with changing industrial practises linked to (for example) automation.”
Our review has set an ambitious goal to reskill and upskill a million workers over the next five years. Its focus, although not exclusively, will be on SME workers (who represent a third of industrial sector employees) through the better coordination of VTQ-related skills initiatives and institutions.'**

Further Education

As the executive summary of the World Economic Forum’s recent White Paper on Reskilling for the Fourth Industrial Revolution points out: ‘Continuous learning lies at the heart of thriving in the context of the Fourth Industrial Revolution. The skills required for most jobs are evolving rapidly but our adult education and training systems are lagging behind. While 35% of the skills demanded for jobs across industries will change over the next five years, only 1 in 4 workers in OECD countries is already reporting a skills mismatch with regards to the skills demanded by their current jobs. Thus, enabling and empowering workers to transform and update these skills is a key concern for businesses and societies across the globe.’**

If the UK is to pursue the goal laid out in The Muted Reviewer to reskill and upskill a million workers in order to give manufacturing the skill base that it requires to thrive in Industry 4.0, the UK will need a robust system of adult education and culture of lifelong learning, or of ‘continuous learning’ as the WEPF White Paper terms it. ‘Lifelong adult education and training is a core part of a successful Industrial Strategy and a precondition to its success’, says The Association of Colleges in its response to the government’s Industrial strategy Green Paper. ‘Action to support adult skills provision in England will raise productivity, help those who are unemployed or on low wages, and ultimately strengthen the country’s economy following our departure from the European Union (EU). To do this, the UK needs long-term investment and reform to improve the availability of skilled and highly-qualified people. Economic success in the coming years will depend on embedding a lifelong learning culture throughout our society. Adults with low and medium skills need to be encouraged and supported to take up learning opportunities throughout their working lives and for all gaps in their basic skills, retain or upskill.’**

Yet, according to government figures, there are 1.5 million fewer adults participating in further education than there were ten years ago. Such is the current crisis in the funding of further education that ‘the number of adult learners fell by 28.8 per cent in just a single year between 2014 and 2015’.** ‘Spending on core adult skills fell by 40% in England between 2010/11 and 2015/16, taking inflation into account.’**

David Hughes, chief executive of the Association of Colleges, writes that: “Further education has been starved of the investment needed to support young people and adults gain the skills they need for successful careers. Without new investment now, we will see more employers failing to fill skilled jobs.”**

So if the funding crisis in further education colleges renders them unable to provide the skills training requisite for the UK to meet its goals in being at the forefront of the robotics and AI industrial revolution, is it down to businesses themselves? Not according to Stephane Karziel, CEO of Upwork: ‘Companies need to look beyond the “not my problem” mentality when it comes to skills acquisition. If nobody takes responsibility for training, simply assuming that some other party (another company, universities, the government) will take care of it, then we have a classic tragedy of the commons. Instead, we all need to contribute to investing in workers’ skills.’**

‘To facilitate this kind of cooperation, there is a big role for public-private partnerships, such as internships and apprenticeship programmes, and vocational training that prepares young people for jobs that don’t necessarily require a college degree, but for which industries have specific skills needs. This model has produced great success in other countries, such as Germany and Switzerland. Both of these countries have demonstrated strong outcomes in procuring adult technical skills and their models could be expanded to other countries.’**

The World Economic Forum’s White Paper sees an opportunity for us to rethink adult education and training to provide workers with the skills that they will need: ‘Growing awareness of technical skills changes associated with the Fourth Industrial Revolution creates a new window of opportunity for concerted action for improving the skills and potential of the workforce of the future at all ages. A new deal for lifelong learning is needed globally to provide dynamic and inclusive lifelong learning systems, to resolve both the immediate challenge and to create sustainable models for the future. Given the right balance, a dynamic training ecosystem has the potential to provide deeply fulfilling careers to future workers while enhancing social cohesion and equity. Policymakers, business leaders and other stakeholders need to work together to ensure that adult training and education systems optimize the availability and competence of the labour force, while providing educational opportunities for all and supporting the entire adult population. This requires multi-stakeholder collaboration and investment in developing robust and dynamic adult training and education systems.”**

Robotics and Future Employment

Although some newspaper headlines over the last year or so are not to be taken too seriously – such as that in the Daily Star on the 4th March 2018: ‘Robot suicide WARNING: Humans to “kill themselves” in jobless AI HELL’, we have nevertheless seen a barrage of negative media publicity for robotics and AI. Some – such as the following headline from the Telegraph – ‘Killer robots will leave humans “utterly defenceless” warns professor’ – are concerned with a supposed human fear of robots, or of AI: ‘Robot WARNING: AI to “replace human mind” as machines take over economy’** – and are often fuelled by youtube videos in the multi-millions of new sub-military-seeming humanoid robots developed by Boston Dynamics, such as ‘Handle’ featured in the Guardian last year. ‘Boston Dynamics unveils “nightmare-inducing” hybrid robot’ or ‘Atlas’, whose youtube video has been watched twenty eight million times.**

Mostly, however, the headlines concern supposed enforced mass unemployment caused by robots and AI taking human jobs, such as the relatively sober headline from the Guardian last year: ‘Robots will destroy our jobs – and we’re not ready for it’**, or with a little more hype from the BBC online: ‘Robot automation will “take 800 million jobs by 2030”’**; or the Daily Mail’s regional analysis: ‘Is YOUR town at risk from robots? Map of Britain reveals the areas where jobs are most at risk from automation as experts warn the “unprecedented change” could wipe out a third of roles’**; or the more urgent ‘AI PEARS: Now save DEMANDED over concerns at speed of super robots taking over our jobs’** from the Daily Express last year, or even “Robots & AI: To “replace human mind” as machines TAKE OVER economy.”**

The recent Deloitte report Talent for Survival: Essential skills for Humans Working in the Machine Age**, written with the economist Carl Benedikt Frey, points out, however, that amidst all the media-inspired dystopian doom and gloom, the reality ‘is far more nuanced and positive than the headlines would suggest: advances in technology create new employment opportunities for people with the right skills and specialist knowledge. Last year, for instance, we looked across 140 years of history in the face of census and labour force data to demonstrate that technology creates more jobs than it destroys.”** ‘Indeed, between 2001 and 2015, we estimated that even as technology had contributed to the loss of 800,000 jobs in the UK, it had helped to create 3.5 million more in the same period. Each new job pays,
on average, an additional £8,000 per annum, resulting in a £640 billion to the UK’s economy in new wages.

David Autor, Professor of Economics at MIT, suggests that “journalists and even expert commentators tend to overstate the extent of machine substitution for human labour and ignore the strong complementarities between automation and labour that increase productivity, raise earnings, and augment demand for labour.”

As Carl Benedikt Frey put it in his work on the Future of Employment with Michael Osborne: “Technological progress has two competing effects on employment: first – as technology substitutes for labour, there is a destructive effect, requiring workers to relocate their labour supply – and second, there is the capitalisation effect, as more companies enter industries where productivity is relatively high, leading employment in those industries to expand.”

We are brought back to Professor Hall and Dr Law’s argument about skills and AI, that ‘the more people who have the right foundational STEM skills, the more can train in the higher skills, but also more will be able to work in adjacent roles: working in and around AI rather than developing it in the most complex levels of training that helps people with the eight basis of knowledge to make this transition would help expand the supply of AI professionals, and could help to develop understanding of how AI can deliver value among a much wider group.’

The Royal Society’s report After the Reboot, cited several times above for its analysis of the state of computing education in schools, makes a similar point about the potential of Robotics and Artificial Intelligence to create prosperity and employment if the workforce is sufficiently skilled to take advantage of the opportunities offered, saying that “while artificial intelligence will almost certainly redefine work roles, it will also lead to net new industries, companies and jobs, many of which are difficult to even conceive at this time.”

In fact, study after study, from the most respected economic scholars and research organizations in the world, indicate that technological advances like AI lead to net job gains. The Organisation for Economic Cooperation and Development (OECD) said it most unambiguously: “Historically, the income generating effects of new technologies have proved more powerful than the labor-displacing effects: technological progress has been accompanied not only by higher output and productivity, but also by higher overall employment.”

Dr Law uses the example of Tesla, for instance, to elucidate the potential of collaborative robotics to create rather than decimate industrial employment: ‘The company’s intelligent robots and machines that cooperate both among themselves and workers in a safe, automated and flexible manner to support capabilities that otherwise would not be possible.’

So, robots will replace some labour, taking industrial ‘jobs’, but what they will replace are the more low-skilled, repetitive and dangerous jobs on the factory floor, while ‘a new generation of “collaborative” robots will also enhance the impact of intelligent automation by maximising the abilities of both humans and machines. As robots become safer and allow close working with humans, the potential applications widen beyond the traditional industries of aerospace and automotive to food and drink, agriculture, biotechnology and the creative industries which are already adding robotic co-workers to their ranks. Based upon preliminary results from an EPSRC sponsored survey by University of Sheffield, University College London and University of Warwick on human and robot interaction, factories of the future will be developed to be adaptive and smart, ‘With superior virtual reality and machine-learning systems, average food technologists can carry out a more varied range of biochemical explorations. Nurses can perform a wider range of imaging tests. Fashion design trainees can contribute more effectively to the fabric technology sourcing process. And so on and so forth. With improving personal agility comes more nimble business models and an expansion of which are already adding robotic co-workers to their ranks. Based upon preliminary results from an EPSRC sponsored survey by University of Sheffield, University College London and University of Warwick on human and robot interaction, factories of the future will be developed to be adaptive and smart.’

The Review sees in collaborative robotics ‘an opportunity for the UK to differentiate itself in this digital industrial revolution. The relatively flexible and competitive UK labour market has allowed many companies to achieve world-class productivity at lower levels of automation. This will provide an even stronger competitive advantage with Industry 4.0 technologies like ‘cobots’, where humans work in harmony with advanced technologies to create highly agile businesses attuned to the changing needs of their customers.

The authors of the Made Smarter Review offer more examples of companies whose use of collaborative robotics (or ‘cobots’) can augment employment as well as productivity: ‘At BMW’s US factory in Spartanburg, cobots help fit the company’s car doors with sound and moisture insulation, a task that used to cause wrist strain for workers. Canadian electronics manufacturer Paradigm Electronics uses cobots to carry out delicate polishing and buffing tasks on loudspeakers, working with employees who handle the final finish and quality check. These robots have led to a 50 percent increase in productivity, but with no job losses – employees who previously carried out these tasks have been promoted from machine operators to robot programmers.’

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If the UK is to indeed act quickly to take advantage of this opportunity to put itself at the forefront of Industry 4.0 by exploiting its potential strengths in collaborative robotics, as with AI, it will need to build ‘a workforce that can best exploit such technological advances’. If the government’s words and, furthermore be mindful that ‘without support for further training and education in RAS and related ICT technologies, the skills taught will not have the skills to react to changes in the global market compared to other competing economies.’
Part 2
OVERVIEW OF CURRENT SKILLS INITIATIVES

With schools currently struggling to produce the requisite skilled future workforce, and the funding crisis in further education colleges rendering them unable to provide an adequate level of adult skills training, what seems to be required is the kind of ‘multi-stakeholder collaboration’ in skills provision that WEFO's White Paper encouraged. Central to such multi-party collaboration are Britain's universities.

The Made Smarter Review; the Department of BEIS’ ‘Green and White Papers on industrial strategy and the DCMS’ Growing the AI Industry in the UK review all agree that universities should play a major role in helping to address the skills deficit in light of Industry 4.0. From the credit-bearing MOOCs and online STEM CPD courses recommended by the AI review to the potential HEIF-backed skills partnership initiatives, Innovation Clusters and Local Industrial Strategies proffered by the BEIS Industrial Strategy White Paper, as well as the proposed Made Smarter Skills Strategy and Implementation Group, universities are expected to work alongside the wider public and private sectors to ‘improve skills, increase innovation and enhance business growth’.

This section will examine some skills initiatives at Sheffield University, the city and beyond and explore what key stakeholders at the university see as their role in upskilling the British workforce in readiness of Industry 4.0.

Collaborative Robotics and Skills at Sheffield University

An Interview with Dr Iveta Eimontaite, Research Associate, Department of Automatic Control and Systems Engineering.

Dr Eimontaite discussed with us her work alongside Dr James Law on collaborative robotics and methods to manage negative attitudes towards robots and robot anxiety in human-robot co-working. She sees one of the central problems of British industrial workers adopting the latest technology and learning the requisite skills to work alongside robots to be that of acceptance, in short that workers don’t trust robotics and fear that robots will take their jobs. Dr Eimontaite feels that workers’ anxiety about robotics and the future of human-robot collaboration largely stems from a lack of accurate information and that general public perception of robotics is largely derived from the media – film and science fiction – in which robots are more advanced than they are in reality.

The robots depicted in films are generally ‘really scary; and the prospect of the future is scary’. Over the course of the research project at Sheffield Robotics, in which workers were invited in to engage with robots and discuss robotics with staff members, who attempted to answer questions put to them about robotics and how they see the future of human-robot collaboration – many of the workers’ anxieties were resolved.

Initially, two groups of ten industrial employees from a factory in which robots were just about to be installed were invited to the lab at Sheffield Robotics to discuss their anxieties and engage with robots in the laboratory. The workers were first asked about their attitudes to robotics and how they see the future of human-robot collaboration and of the future of manufacturing in general and what role they saw robots playing in it. They were then given a guided tour and could meet, touch and otherwise engage with the robots and ask the attendant academics any questions. Dr Eimontaite reports that safety was the primary issue that the industrial employees were interested in discussing; most were working with welding equipment and were keen to discuss ways in which working with robots could improve their safety. With a robot between them and the welding equipment, they saw how collaborative robotics would make their jobs safer; there would be fewer accidents and in the end ‘they were more eager to interact with robots than with the welding machines’. By the end of the workshop, there was a 40% drop in the workers’ fear of robotics and anxiety about working alongside robots. Good directions – in terms of signage and information provided by the academics at Sheffield Robotics – were also shown to be significantly important in easing the anxieties of the co-workers and increasing their productivity working with the collaborative robots.

Dr Eimontaite concluded that effective public engagement is vital to aid acceptance of robotics and encourage workers to upskill themselves to work alongside robots. ‘We all know that changes are going to happen’ she says, ‘the important thing is to involve people in those changes, so that they happen with people, not to people.’ When the factory workers had actually interacted with robots, seen what they can and can’t do, and discussed what aspects of their jobs they would like robots to do for them, they were far more open to robotics and to working collaboratively with them. Dr Eimontaite went on to discuss how engagement is important for people of all ages; a public engagement exercise that she carried out with 3-5 year-old children at the laboratory was also highly successful in her view. She found that the children were far more accepting of robotics, excited to be in the presence of actual robots and curious about what they could do, so that in the end, the children ‘wanted to do more things and weren’t afraid of technology but encouraged to work with it.’
De Einoraita felt very strongly that there needs to be more collaboration between academia and industry to help the British workforce collaborate and seek to acquire the skills they need to work with the new technology. The research she has carried out at Sheffield Robotics with De Law demonstrates that if people are engaged with new technology, by getting the opportunity to interact with it, they feel far more empowered to actively participate in technological innovation. One way of getting the expertise and technology out of the university and into the engineering workforce is to engage with industry and universities working together; without engaging the public, and children, sufficient progress won’t happen.

Just as important as public engagement is the research Dr Reilly has been involved in – such as the International Women in Engineering Day event done at the Winter Gardens in Sheffield and the annual Sheffield University Women’s Engineering Day event. De Reilly prizes public engagement highly, finding it an important way to attract people to a career in engineering. Events such as those above are good for showing people the latest technologies and letting them interact with them. Especially in the case of engineering, Dr Reilly commented that people often don’t understand what engineering actually is, that it’s not just a case of fixing people’s broken washing machines or going to work on a building site, but can be an opportunity to work with the very latest technologies, that people at the events can see these technologies in action and experience different roles. The key thing, she related, was not trying to force young people into any particular field, but to inspire them to get interested in engineering as a broad field with lots of exciting and engaging technologies.

Public engagement can be a vital way to attract girls to engineering, she thought. As Faculty Director of Women in Engineering, De Reilly expressed her pride that she managed to push the ratio of women studying mechanical engineering up to 28% and the faculty as a whole up to 22%, but these figures are obviously still very low. ‘You’re not going to get more female postgraduates if you don’t get the undergrads and you’re not going to get the undergrads if girls aren’t doing the right A Levels, and so on.’ What annoys Dr Reilly stresses the need to combine more public engagement with research so that we can develop the most productive graduates possible, to follow the long-term consequences leading from the initial inspiring contact with new technology. As she says of the annual Women in Engineering Days that she helps run at the Winter Gardens in Sheffield – ‘they’re always full and you certainly get a very positive response. All we know is that there has been a slight increase in engineering applications from women, but it’s workforce and once women have got into the workforce, and it is vitally important to engage with younger generations before the social conditioning has taken hold.’

As De Reilly argued, though, ‘how many age groups can we target? We’re universities and we have to think primarily of the people we’re recruiting to. The real problem is that there aren’t enough girls doing physics, mathematics, engineering – they don’t deal with that is doing extra physics training in the summer and other activities like that. It’s not just girls, it’s all students to have to do but it’s the only way to address the balance because there’s such a small pool of people who do have physics A level.’ Dr Reilly went on to explain that ‘we know that in the long run, more experiments in engagement is with long-term cultural change that makes engineering more accessible to female students and that the way to do that is with public engagement and getting the message out there.’ The problem, though, is that for academics such as Dr Reilly, the immediate priority has to be to ‘getting buy-in seats in the very short term; recruiting undergraduates.’

Dr Reilly sees great value in wider public engagement, however. In terms of adult education, she feels that ‘the older generation to robotics through public engagement initiatives is key to reskilling the workforce, but not just the workforce. Dr Reilly prizes public engagement highly, finding it an important way to attract people to a career in engineering. Events such as those above are good for showing people the latest technologies and letting them interact with them. Especially in the case of engineering, Dr Reilly commented that people often don’t understand what engineering actually is, that it’s not just a case of fixing people’s broken washing machines or going to work on a building site, but can be an opportunity to work with the very latest technologies, that people at the events can see these technologies in action and experience different roles. The key thing, she related, was not trying to force young people into any particular field, but to inspire them to get interested in engineering as a broad field with lots of exciting and engaging technologies.

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Working with James Wallbank, for example, Professor Marsh relates that she has been about drawing their skills and knowledge in. ‘These are people who have been working for years, often with open-software tools, in their own communities. They’re very skilled and knowledgeable people; it’s about drawing their skills and knowledge in.’ Professor Marsh relates that she has been working with more technologically disadvantaged communities, ‘asking them what they need’ and adapting our work accordingly when researching such public engagement initiatives.

As well using undergraduate and graduate volunteers on the buses, or in Makerspaces generally, Professor Marsh is keen to bring in the Makers to enthuse and inspire people into STEM. ‘These are people who have been working for years, often with open-software tools, in their own communities. They’re very skilled and knowledgeable people; it’s about drawing their skills and knowledge in.’ Professor Marsh relates that she has been working with James Wallbank, for example, who runs the Access Space Network charity and a Makershop in Sheffield, on projects working with 3-4-year-old children to enthuse and inspire them into a life of Making and STEM.

Makers such as James Wallbank and potential initiatives such as Maker buses could also be highly effective in reaching adults in more technologically disadvantaged communities. Again, Professor Marsh feels that it is important to consult and collaborate with such communities as to their needs and design projects accordingly, using Maker technology to solve real-world problems in community settings so that communities themselves can invent and create the tools they need to address problems they face. ‘You can have multiple projects and multiple age groups’ Professor Marsh says ‘it’s not too late to enthuse someone around STEM – there’s an urgent need I think for early and mid-teens, to orientate them towards these areas’. Female role models are vital in such work if more women are to be encouraged to pursue STEM careers and adopt more STEM skills. ‘That is how MakeY’ started’ Professor Marsh relates. ‘I went to the Fab Lab in Berlin and they were all male. I thought to myself: this can’t be right, we’ve got to get girls interested.’

Some skills initiatives... outwith TUOS

Interview with Catherine Elliott, eLearning consultant, Sheffield City Council

Catherine Elliott started the interview with us by discussing her successful Nesta-funded Make:Learn:Share project, a citywide ‘Made in Sheffield’ Young Ambassadors programme looking to train 135 year 8 & 9 schoolchildren in digital making for them to then deliver technology workshops to younger children in local primary schools.

‘We’ve done really well at recruiting girls’ she told us. ‘We’ve had good gender splits and a couple of all female groups.’ Catherine remembers that their initial aim was to get a 50/50 gender split in the young ambassadors’ groups, or at least good female representation, ‘but a lot of the teachers in Key Stage 3 decided the program would be a good way of trying to get year 8 and 9 girls enthused in computing before taking their options, so some made a decision that they were going to actually target the girls.’ She considers that the fact that she and fellow project leader Sue Finnigan are women helped in attracting so many girls to the programme, being good role models for them, but says that it also grew out of how they set up the coding project, ‘by including design, social aspects, ethics and making it a more rounded experience to attract a wider range of young people.’ Mrs Elliott reckons that overall ‘we’ve trained approximately 150 students from year 8 to year 10, and probably just over 50% of these were girls. One school brought 100% girls to the training session.’

‘Real-world’ activities are also seen by Catherine as being a good way to bring girls and young children generally to STEM. Whereas schools don’t have sufficient space in the curriculum and school day for children to enjoy many extra-curricular activities, the Make:Learn:Share making sessions offer children the opportunity to experiment more in open-ended activities and to talk around computing. ‘Students are very interested in the ethics of robotics and data’ for example ‘I’ve seen how motivated these kids are by having lots of different ways into technology.’ The idea of being an ambassador and teaching coding to other younger children, instead of just learning it, has also worked in engaging girls.

Mrs Elliott highlighted recent work by The Salters’ Institute and Salters’ Horners in attracting more girls to science by developing real-life, practical physics and chemistry projects to engage children and get them more interested and active in non-formal educational settings such as the Salters’ festivals and summer camps.
Interview with Howard Baker, creator of the Micro:bit and consultant on education and technology

Howard Baker, creator of the Micro:bit, told us that although schools remain the easiest and most efficient way to teach large numbers of children, training teachers to ensure that the skills that children possess are vital if the children’s computing and STEM skills are to be genuinely improved. As such, educational projects such as the Royal Society of Chemistry Festivals in Schools and the DCMJS’ report on growing AI in the UK attest, many computer science teachers did not originally study computing at degree level but instead have backgrounds in IT or lack the requisite skills to teach the pure computing segments of the GCSE.

As Mr Baker says – ‘it was just about working with Excel and Word and treating the computer as a black box, teachers didn’t really need to know how the computer was actually working’.

With the support of Microsoft, the Micro:bit Foundation found that the open-ended, hands-on pedagogical approach of teaching teachers about computing using Micro:bits was highly effective, largely because it enabled teachers to gain confidence in their understanding of computers and ability to teach children. After piloting the technology with 11 year-olds in a whole range of computing and STEM jobs that aren’t just coding and pure science, but that STEM teaching can lead to successful industries as well. ‘The files could feature young people in the creative industries around Sheffield – web development, animation, etc. for example – who could describe what they do and the skills that they needed to get there.’

Mrs Elliott was also very interested by the idea of a Maker bus as an engagement tool. ‘It would work well in schools is that there is no time or money; schools can often only dedicate an hour every fortnight to teach computer science and they need the help of universities and businesses to provide real-world experiences around computer science. Sometimes nobody ever gets to people who aren’t currently engaged and who need the skills would be really interesting. We could use the young ambassadors to help. There’s a huge desire in schools to address the gender imbalance and the teachers don’t want to say that we could do a roadshow to address the imbalance, the schools would be keen to help.’

Providing multiple routes into technology is key to attracting children and girls to the Make:Learn:Share project but Mrs Elliott also believes that simply providing the basics is insufficient, giving them the skills base that they will need later in their lives. ‘Look into the future and think about what you want to program but that everyone will have to be aware of how technology impacts their jobs.’

These are the skills, Mr Baker thinks, that we will need in the future – problem-solving skills using technology, overall STEM skills. Although micro:bit projects like this have the potential to be taught separately, schools should still be taught separately, children should still be taught separately. ‘Some schools are able to run STEM projects in the background, like the micro:bit Race for girls, having a little bit of coding, we teach kids design rocket cars. They use maths, science, physics, chemistry and engineering all together. Light and Air project, where they get to design and build a free Think of it like this a real-world problem-solving potential, Mr Baker believes that it might need some help. ‘We thought that being really highly effective. He uses the example of an 12 year old Maker and young coding ambassador Femi, who is in the process of starting a series of workshops and courses and advises businesses, including running a micro:bit robot workshop for the WISE event, as well as his work in community coding and making events. ‘We use kids as ambassadors’ Mr Baker concludes, ‘we should be doing the utmost to facilitate, enhance and create access to informal learning. It builds confidence and awareness’, we should do everything we can ‘to give kids meaningful contact with technology’. The gender split in STEM is also an important issue for Mr Baker. As reported in press reporting of 1 of this report, he feels strongly that we must work to show girls that getting access to STEM for girls; STEM must be made more socially acceptable as a career route for girls as well. ‘The problem as Mr Baker points out is that simple ‘drag and drop’ technology of the Micro:bit relatively easy to comprehend rather than being anxious about their ability to understand the Micro:bit, as gender neutral as possible’ he says, ‘the design, the access to it and most importantly the fact that the code can be completed by girls, or boys, or anyone who feels they don’t want to create them themselves, but they would in if a good project came then they would do it at capability. There is the feeling that project-based learning can lead to good exam results in the separate STEM exams, what the BBC tried to create was a ‘real-life problem-solver not just a coding tool. Informal learning is extremely important’ Mr Baker continues, ‘we should be doing the utmost to facilitate, enhance and create access to informal learning. It builds confidence and awareness’, we should do everything we can ‘to give kids meaningful contact with technology’.

‘It’s a step by step process’, he says, ‘if you’re a novice at computing and coding, learning elementary programming with the basic Micro:bit, this can be the right support; we tried to make it as easy as it could be, yet proving that they have the initial experience, once they have grabbed it and seen how easy it actually is and see that it’s just the perfect thing, they consider moving on to the next stage of making, attaching lights or speakers or joining creative networks. We have considered that they can think we could possibly build a robot and I could join or support a making club or coding club or Scratch club and they can think of ideas that they can take out of the box and have it as proved by the community of text messages or animation sharing, after just two or three instructions. It makes everyone feel involved with such an engaging community, it gives them confidence. We see it very much as a skills-based tool. It’s very much about computational and computational and computational thinking.’

SKILLS AND EDUCATION FOR ROBOTIC AND AI (SERAI)
Thinking about the skills that the next generation will need to thrive alongside the new technologies, Mr Rose surmises that there’ll be fewer and fewer coders. The problem is never finding enough coders, what we’ll need is communication skills, domain expertise and understanding some of the constraints and limitations of the platforms. Whether you’re a coder, an engineer or a scientist, what everyone needs is a general understanding of what’s going on.

‘Coding clubs, Lego League clubs, engineering clubs – all these clubs are good – just for getting young people engaged early and showing them that they don’t have to be a top student in anything to do it; we specialise too early as it is. The main thing is to demystify science and computing. Computers aren’t off limits and impossibly complicated. Everyone can do it.’

‘Seb feels that we should ‘give kids a broad understanding of what’s going on.’ What employers want is ‘people that can adapt, someone who can work in a team and has broad knowledge – your classic T-shaped person – broad knowledge in a domain and deep knowledge somewhere. Put them in a team and as long as they have good communication skills, they’ll be fine.’

"Computational thinking can be a confusing term, but it basically means enabling people to think about solving problems with technology. AI on its own and people on their own are not as strong as both together." What we’re encouraging people to think about is ‘how can I solve problems using machines to work with me? What we need is a fundamental literacy of understanding what machines do, how you define problems and what the limitations of machines are. How we get people working with machines: that’s the future skill.’

Mr Gibbs largely agrees with Mr Rose’s thoughts about computational thinking rather than coding per se being the skillset that employers now and in the future will require as Industry 4.0 gathers pace. ‘Computational thinking can be a confusing term, but it basically means enabling people to think about solving problems with technology. AI on its own and people on their own are not as strong as both together.’ What we’re encouraging people to think about is ‘how can I solve problems using machines to work with me? What we need is a fundamental literacy of understanding what machines do, how you define problems and what the limitations of machines are. How we get people working with machines: that’s the future skill.’

The key, Mr Gibbs feels, is to ‘give people exposure to new technologies and highlight the skills that they keep re-applying in solving problems with it.’ Mr Gibbs relates how there’s currently some good work being done in primary schools with explicit goal labelling – helping children decompose problems and understand that they are using the same adaptable STEM skills every time. With such an adaptable core set off skills, the future workforce of the Fourth Industrial Revolution would have the tool kit they need to work
alongside machines and solve whatever problems industry throws at them.

Imbuing people with a core set of STEM skills is the best strategy we can employ. It’s difficult in secondary schools, however, where the individual subjects are siloed because exams have to be passed and targets met. ‘Extra-curricular groups and initiatives are probably the only way to implement it now.’

**Part 3**

**CONCLUSIONS AND RECOMMENDATIONS**

**CONCLUSION**

If we are indeed to ‘reap the greatest rewards’ from the opportunities presented to us by Industry 4.0, as the Business Secretary wrote, we ‘need to prepare to seize them’100. Instead of fearing robotics and AI, two of the main drivers ‘turbo-charging’ the fourth industrial revolution, and lamenting the economic and social disruptions that they might bring, we should embrace the opportunities that they provide and trust that now as previously the ‘income generating opportunities that they provide and trust that now as previously the ‘income generating effects of new technologies have proved more powerful than the labour-displacing effect’101 leading to higher not lower overall employment and prosperity.

Following Goldin and Katz’s well known maxim that industrial revolutions represent a race between technology and education102, the key to the UK fully embracing the opportunities offered by Industry 4.0 is skills and education. ‘Investing in all our skills is at the heart of building an economy that is fit for the future’ as CBI director-general Carolyn Fairbairn put it so succinctly. ‘Skills are vital to competing globally – and seizing the opportunities of the fourth Industrial Revolution’103. As we have seen from the many responses to BEIS’ Green Paper Building Our Industrial Strategy104 and from the several other sources quoted in this report, it is vital that we acknowledge and confront the current skills deficit in the UK by meeting the inherent weaknesses in our skills base head on.

As well as the skills in robotics and related ICT technologies that Dr Law tells us we will have to put in place if we want to compete with other major economies in the global market105, it is also the more basic STEM skills of the population, developed through primary and secondary education and on into adult life, that the UK will have to improve if it is to climb up the skills tables and prosper in the digital era.106 In terms of computer science education, crucial to the UK attaining adequate foundation skill levels, ‘44% of secondary school teachers only felt confident teaching the earlier stages of the curriculum where there is less of a computer science focus’107, while about a quarter of the secondary school teachers surveyed by the Royal Society reported that they had not undertaken any computing-related CPD in the last year to help them gain the requisite understanding of computing to teach others.108

Many commentators quoted in the report above point out that a major factor explaining our low relative international position in digital and STEM skill levels is our gender balance in STEM and digital education and employment. The figures speak for themselves. At GCSE, there is only a 28% take-up of girls studying computing, which falls to 9% at A level. Only 21% of the STEM workforce and 15% of the ICT workforce are female; women make up only 25% of those graduating from degrees in STEM subjects. The proportion in engineering is still lower at only 8%, with the unenviable consequence that the UK has the lowest percentage of female engineering professionals in Europe.

As well as the several published sources quoted above, our interviewees have also provided ample evidence that the current concentration on teaching coding per se as a means of attaining the requisite higher skill levels for the UK to prosper in the fourth industrial revolution may be insufficient. As Dave Gibbs, Sab Rose, Professor Marsh, Catherine Elliott and Howard Baker told us, Industry 4.0 will require a wider, adaptive skill set, centred more on creative problem solving and computational thinking rather than straight coding skill. As Dave Gibbs put it: ‘What we’re encouraging people to think about is ‘how can I solve problems using machines to work with me. What we need is a fundamental literacy of understanding what machines do, how you define problems and what the limitations of machines are. How we get people working with machines: that’s the future skill.’ Many of the academics and experts interviewed above also see this more adaptive, agile, hands-on and informal set of skills and learning outcomes to be a more effective way of encouraging girls and women into STEM, especially technology and engineering. Crucially, it must be also made more socially acceptable for women and girls to engage in STEM.
Further education has been starved of the investment needed to support young people and adults gain the skills they need for successful careers’, let alone meet the Mode SmartCity’s skills audit that two million people will potentially need to be upskilled or reskilled in the workplace.

For the British economy and society to thrive in Industry 4.0, it is important that we establish a culture and system of continuous learning – upskilling and retraining – to optimize the availability and competence of the workforce. Effective adult skills training becomes ever more vital with our ageing society; increased awareness and acceptance of technology can give older people not just a more economically productive but also a more connected and fulfilling life in their older years.

With much of the issue being a structural one – that children are not leaving school with sufficient skill levels and that much of the current workforce lacks the skill levels that will be required by Industry 4.0, it is also too much of a job for universities alone to take on board. As Dr Reilly commented in terms of addressing the chronic gender imbalance in STEM ‘how many age groups can we target? We’re universities and we have to think about industries that are ready to come on board. As Dr Reilly commented in terms of addressing the chronic gender imbalance in STEM ‘how many age groups can we target? We’re universities and we have to think about industries that are ready to come on board.

Along with basic skills, another major issue with the potential to prevent the UK maximizing the opportunities of Industry 4.0 and not pay heed to Professor Maier’s observation that ‘we haven’t reached our full potential and have left too many of the opportunities arising from the Third Industrial Revolution to other nations’ is the public perception of robotics and AI largely fuelled by a dystopic vision of the future beloved of movies and the mass media that they will take human jobs and ultimately kill us all. As we have seen, however, the reality is far more nuanced in the words of the Deloitte Report written with Carl Benedikt Frey – and that ‘advances in technology create new employment opportunities for people with the right skills and specialist knowledge.

Collaborative robotics, particularly, offers an alternative vision of the future in which Britain especially can thrive.

Although universities alone are unable to confront and resolve the UK skills deficit in the light of Industry 4.0, there is a major role that they can play in partnering with private companies and training organisations in the kind of ‘multi-stakeholder collaboration’ in skills provision that WEFO’s White Paper on reskilling encouraged. With universities’ backing, such collaborative bodies can research and implement the requisite methods to train the ‘two million people [who] will potentially need to be upskilled or reskilled in the workplace’.

Such a body may also look at the work of partnering organizations such as the Salteers’ Institute, who confronted the skills deficit in chemistry with public engagement and outreach programs as well as curriculum development at GCSE and A Level, working alongside the University of York. Led by the University of Bath, twenty five universities, including Sheffield, a founding member, are similarly linked to the Institute of Coding, which helps address the digital skills and computer programming deficit in the UK.

An intriguing and highly successful collaborative model is the Fab Foundation, a not-for-profit movement founded in an educational outreach program by MIT in 2008 to facilitate the spread of a ‘fab lab’ network throughout the US and internationally, in partnership with corporate sponsors. The Fab Labs themselves, such as the one that Professor Marsh has visited in Berlin, utilize hands-on project-based digital fabrication, electronics and computation in an open, informal environment to bring the university’s resources to the public to help educate, upskill and inspire communities in STEM. Mobile Fab Labs look to take community manufacturing technology, such as laser cutters, 3-D printers and milling machines to more rural or disadvantaged areas.

With its strong history in manufacturing and the university’s burgeoning reputation in engineering and robotics, Sheffield would see an ideal leader in such collaborative partnerships to provide the curriculum development, skills training, outreach and effective public engagement that is needed to produce a workforce sufficiently skilled and accepting of robotics and AI to help the UK thrive in Industry 4.0.
RECOMMENDATIONS

There is the opportunity to establish a sustainable program of public engagement and outreach services, hands-on skills training, curriculum development and CPD in Robotics and Artificial Intelligence in line with the UK government’s new Local Industrial Strategy and Digital Skills Partnerships program and building on the success of Sheffield and the AMRC as the UK’s first digital innovation hub.

This programme can:

• Address and resolve the R&AI skills deficit with both formal and informal initiatives, on one hand developing formal teaching resources and methodology such as software, AR, MOOCs, course material and consultancy and on the other hand developing informal public engagement and outreach activities for community, adult, and after-school skills and awareness programs.

• Initiate and pilot a new public engagement and outreach program utilising Making and Makers to engage, inspire and demystify STEM, R&AI and new technologies. Robot Maker Centres could be opened in hub cities to attract people of all ages and backgrounds to informal, open-ended technology courses and interactive workshops. Robot Maker Buses could travel to remote community centres and libraries to reach more rural and disadvantaged communities. By scaling the program in this way, a significant national impact could be created on skills and education in robotics and AI.

• Make Sheffield the first Skills and Education for R&AI (SERAI) hub in the UK while also developing other local partnerships based around universities and robotics centres to create a hub-based public training and outreach network throughout the UK.

• Develop and maintain strong relationships with potential partners, such as with the public engagement and outreach and Institute of Coding teams at the University, the eLearning team at Sheffield City Council; Sheffield Digital, the national STEM Centre; the Micro:bit Foundation; AMRC; and with outstanding Sheffield technology companies such as leading 3-D and software developer Autodesk; and Pimecuni, the UK’s second-fastest growing manufacturing company.

• Generate strong positive publicity for R&AI with a concerted campaign of podcasts and live webcasts, films and press releases to counter the often negative portrayal of R&AI in the mainstream media and to encourage more women and young people into new technology careers.

• Continue and expand the highly successful work of the AHRC-funded Cyberselves project, to encourage acceptance of R&AI and familiarize more communities with new technology by utilizing Sheffield Robotics’ resources to engage, entertain and educate people in the potential of R&AI. Livestream broadcasts from Cyberselves events and continue generating positive publicity with blogs and press releases. Attending corporate functions and events could help make SERAI sustainable, while developing a SEND program, piloting the use of social robots such as MiRo in SEND schools, would extend the reach of SERAI’s skills initiative.

Such an initiative could be supported by grant income; licensing; consultancy and training fees; and with robot demonstrations and exhibits for for-profit and not-for-profit organisation. Some of these activities could be operated in-house by Sheffield Robotics and the University of Sheffield, however, the broader aims discussed may extend beyond the University’s core mission, and therefore parts of this programme may suit the formation of a for-profit or not-for-profit spin-out organisation that partners with the University.
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