



Foreword

You may have heard that robots are coming for your job. Rapid advances in robotics, big data and artificial intelligence are beginning to disrupt entire industries, and technology is threatening to replace more than ten million UK workers. But a new debate is now raging between those who argue that we are ushering in an era of unprecedented technological unemployment, and those who claim that job prospects for people with the right mix of talent have never been better.

While the debate rages on, we have been examining the data that allows us to understand the changing demand for individual skills, knowledge and abilities caused by technology shifts.

Based on our analysis, we believe that, although Science, Technology, Engineering and Mathematics (STEM) skills and knowledge are important in an increasingly digital economy, the UK will benefit most from a workforce that has a balance of technical skills and more general purpose skills, such as problem-solving skills, creativity, social skills and emotional intelligence.

We forecast that by 2030, such will be the demand for these general purpose skills that meeting it will require the equivalent of at least 4.5 million additional workers in professional occupations. We have also found that social skills and cognitive abilities are valued most in our shifting economy – a 10 per cent increase in cognitive abilities equates to a 12 per cent increase in median hourly earnings. But not all important skills and knowledge contribute to wage increases: the UK still has some way to go before vital jobs in education, health and social care, and many other nationally significant industries, feel the benefits of a workforce with the right mix of skills.

The UK may have significantly fewer jobs at high risk of automation than the likes of the US, China, India and South Africa, but there is no room for complacency. There are considerable challenges that policymakers, educators, and businesses have yet to overcome.

This paper is the latest in Deloitte's ongoing 'Business futures' research programme, which aims to provide insights into business in the future. We are committed not only to examining the potential impact of digital technologies on the labour market, on occupations and on different sectors of the economy, but also to helping our own workforce and the community adapt to life in the machine age.

We hope that you find this paper useful and look forward to your feedback.



A handwritten signature in black ink, reading "Angus Knowles-Cutler".

Angus Knowles-Cutler
Vice Chairman and London
Senior Partner



A handwritten signature in black ink, reading "Harvey Lewis".

Harvey Lewis
Director and Corporate Insight Leader

Introduction

“We should automate work and humanise jobs. Let’s give the mundane to the machines and the purpose back to people.”

The Rt Hon Matt Hancock MP¹

Conventional wisdom suggests that growth, productivity and innovation in a digital economy all require a supply of workers with matching digital skills, knowledge and abilities. This theory is supported by a growing body of evidence, according to the recent Wakeham Review, which notes that the majority of growth sectors in the UK are characterised by their strong reliance on Science, Technology, Engineering and Mathematics (STEM).²

In anticipation of a continuing shift towards greater use of technology and automation, the UK government has already instigated numerous policy changes, including introducing a new National Curriculum for schools, to ensure that the future stock of workers can meet increasingly technical employment requirements. Yet unemployment rates among recent graduates of STEM degrees remain paradoxically high. Are we still waiting for the promised transformation of the economy? Do businesses really need workers trained in STEM? Or are the UK’s schools and universities simply failing to produce young workers with the necessary skills and knowledge?

Neither the Wakeham Review nor its sister investigation, the Shadbolt Review of Computer Sciences, have been able to pinpoint a precise cause.³ But both reviews do highlight the critical importance to employers of a broader set of general purpose skills and knowledge, including ‘soft skills’. And in their recent book, “Only Humans Need Apply: Winners and Losers in the Age of Smart Machines”, authors Thomas H. Davenport and Julia Kirby argue that, “We’re entering an era when these soft skills will be more important than ever, and for many people they will be the best hope of gaining and maintaining employment.”⁴

Deloitte’s previous research estimated that 35 per cent of the UK’s jobs are at high risk of automation in the next 10 to 20 years as a result of the introduction of automation and other labour-saving technology.⁵ The UK’s economy may well be less exposed to the effects of automation than some others – in China,

for example, the number of jobs estimated to be at high risk of automation is 77 per cent – but this hasn’t prevented the ‘techno-pessimists’ from forecasting that humans will become obsolete in the future.⁶

The reality, though, 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 form of census and labour force data to demonstrate that technology creates more jobs than it destroys.^{7,8} 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 £10,000 per annum, resulting in a boost of £140 billion to the UK’s economy in new wages.

This optimistic view is consistent with the principle of “stepping aside”, introduced by Davenport and Kirby in their book, in which it is claimed that there will be more jobs that lay the emphasis on skills at the “humanlike” end of the spectrum rather than being focused on fact, recall, logic and computation.⁹ David Autor, the eminent MIT academic, 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.”¹⁰ And Carl Benedikt Frey, co-author of “The Future of Employment” and contributor to Deloitte’s work on automation, says, “I think it unlikely that robots will enter the domain of complex social interactions or jobs that require creativity or perception, and manipulation of irregular objects.”^{11,12}

So while it feels intuitively necessary in an increasingly digital world for policymakers and educators to focus on the acquisition and application of STEM knowledge and skills in the workforce, STEM by itself is not sufficient to ensure future employability or economic prosperity. Instead, we need to consider what skills, knowledge and abilities are needed for the vast majority of jobs as well as those that provide workers with the flexibility to adapt to or specialise in a range of roles. Every worker needs a balanced 'kit bag' of skills – not simply to avoid being substituted by machines but also to help them adapt to working alongside machines in a smarter, more efficient and productive economy.

This new research thus follows on from previous Deloitte studies into the impact of technology on jobs. Using detailed occupational data from the US Occupational Information Network (O*NET) and labour and earnings statistics from the Office of National Statistics (ONS), we assess the importance of 120 different skills, abilities and areas of knowledge in the workforce as the mix of occupations changes as a consequence of the introduction of smart machines and automation. We consider the impact nationally and also by main industry sector and occupational group. And, we forecast the likely impact that these ongoing shifts will have on the economy in 2030. Finally, we discuss the challenges that all organisations are likely to face, and provide a set of key questions for policymakers, educators and business leaders to answer.

Summary of our main findings

Our research shows that:

- **Essential human talents are dominated by cognitive and social skills.** The academic knowledge and technical skills that many students acquire during their school and university lives provide them with just a fraction of the skills and abilities that will be essential in their careers. Rather than just focusing on STEM and digital skills, future workers need to acquire a more balanced scorecard of talents, building up essential cognitive, social, process, content and problem-solving skills and abilities, as well as knowledge, and learning how to apply these in relevant contexts so they can become more employable.
- **Brains are more important than brawn.** In absolute terms, knowledge of specialist STEM subjects is 40 per cent more important than the physical abilities of strength, endurance, flexibility or the ability to manipulate and control objects. However, general-purpose complex problem-solving skills and social skills are over twice as important. Complex problem-solving, social and process skills, which contribute to the more rapid acquisition of knowledge and skill across a variety of domains, were the most important qualities in the UK's workforce, overall, in 2015.
- **Social skills and cognitive abilities are valued most in the national economy.** A ten per cent increase in the importance of cognitive abilities, which influence the acquisition and application of knowledge, contributes to a 12 per cent increase in median hourly earnings. The same increase in the importance of social skills contributes to a ten per cent increase in median hourly earnings. However, although the importance of health services knowledge is forecast to increase by over 17 per cent by 2030, every ten per cent increase in importance contributes to a two per cent drop in pay.
- **Increased demand for STEM and other skills will require millions more professionals by 2030.** By 2030, mathematics and science knowledge will have increased in importance by eight per cent. This is equivalent to adding approximately 4,500,000 new STEM-enabled professional occupations to the workforce, including teachers, scientists, engineers, IT and digital professionals, economists and statisticians.
- **The proportion of jobs at high risk of automation is related to investment in education.** In our analysis of a number of national economies, we find that the investment that governments make in education is closely related to the percentage of jobs at high risk of automation. In the UK, 35 per cent of jobs are at high risk of automation while the government invests 5.7 per cent of its GDP in education. In India, by contrast, 69 per cent of jobs are at high risk but only 3.8 per cent of GDP is invested in education.

Shifts in the national economy

“We should embrace robots, not fear them.”

Andrew McAfee¹³

During the early 19th century, the East Midlands was the UK's centre for framework knitting, with large numbers of trained workers using machines that could produce knitted products 100 times faster than someone knitting by hand.¹⁴ However, as new frames were introduced by master hosiers, which could double or even triple the amount of cloth knitted at one time, the framework knitters rebelled, fearing that their livelihoods would be taken away by the advancement of technology. They began to smash the new machines and thus the Luddite rebellion was born. At the height of the movement, attacks on the knitting frames were so widespread that there were more soldiers of the British Army keeping the peace in the East Midlands than there were in Spain fighting Napoleon in the Peninsular War.

Fear of unemployment caused by advancing technologies is nothing new, therefore. Yet the evidence suggests that workers should have little to fear. According to David Autor, the employment-to-population ratio rose during the 20th century.¹⁵ And our own research shows that for the last 140 years, technology has been a “great job-creating machine”.¹⁶ Although there is no ‘fundamental economic law’ that guarantees a worker proper employment, we suggest that rather than sparking a second Luddite rebellion, innovations in robotics, process automation, artificial intelligence and big data should be embraced for the new opportunities they will create for workers who possess the right skills, knowledge and abilities.

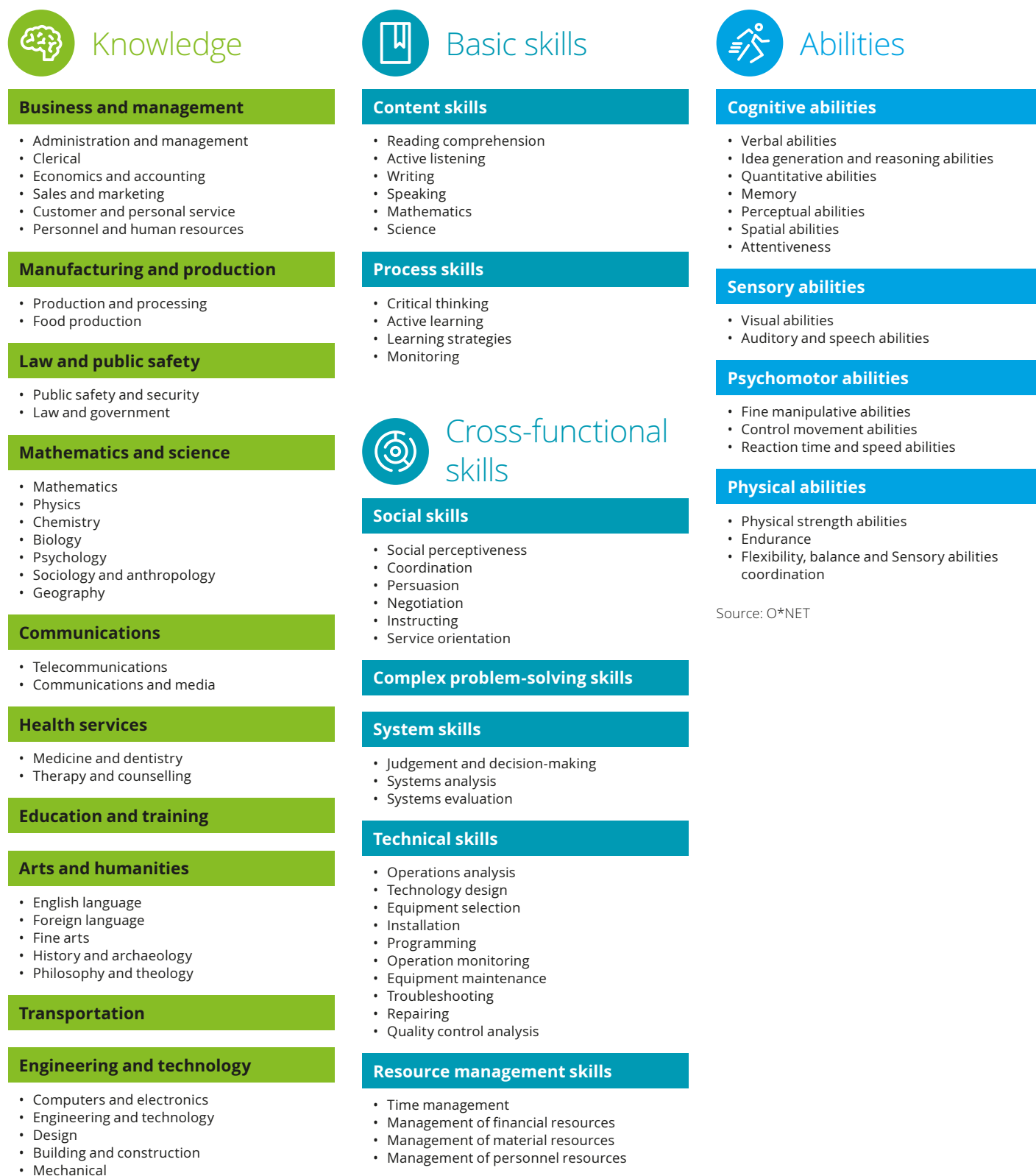
So what human talents are needed for work in the machine age? To answer this question, we have used resources from the Occupational Information Network, which has been developed under the sponsorship of the US Department of Labour/Employment and Training Administration.¹⁷ The O*NET database contains information on the importance of hundreds of standardised and occupation-specific descriptors, which are continually updated by surveying a broad range of workers from each occupation. We have taken 120 distinguishing skills, knowledge and abilities characteristics of the O*NET occupations and mapped these to the equivalent UK Standard Occupational Classification (SOC) using a mix of available ‘crosswalks’, employment data published by the US Bureau of Labor Statistics, the Computer-Assisted Structured Coding Tool (CASCOT) developed by the University of Warwick's Institute for Employment Research and, in the relatively small number of remaining cases where the mappings were indeterminate, our own judgement.¹⁸

According to O*NET:

- Knowledge is the theoretical or practical understanding of the facts and principles about a subject or domain of information.
- Skills are the proficiencies we develop through training or experience that allow us to work with given knowledge. Basic skills, such as reading, facilitate learning or the acquisition of new knowledge. Cross-functional skills, such as problem-solving, help us perform a range of activities across our jobs.
- Abilities are the qualities of being able to do something, such as physical strength, which allows us to lift or move things, or our ability to come up with original ideas – one of several cognitive abilities.

The elements of the O*NET content model we have used in this study are illustrated in Figure 1.

Figure 1. Talents used in this research




























What human talents are most important?

For each skill, ability or knowledge domain, we calculated the percentage of the total workforce – approximately 31 million people – for whom the characteristic would be of medium or high importance using a scale running from the least important to the most important talent. Talents that are important to the vast majority of the workforce can therefore be considered foundational – everyone needs them if they are to perform their job well and contribute effectively to the UK's economy. These essential talents, vital to 90 per cent or more of the workforce, are listed in Figure 2.

The full ranking of the 120 different skill, knowledge and ability attributes highlights two key issues:

- **Knowledge is not an essential talent:** with the exception of mathematics (which is important to 87 per cent of the workforce), knowledge of administration and management (86 per cent), knowledge of education and training (79 per cent) and knowledge of computers and electronics (72 per cent), academic knowledge, for instance in the physical or natural sciences, or the arts and humanities, is important for only a minority of the workforce.
- **Digital and technical skills are specialisms required by only a minority of workers:** programming skills or technology design skills are important to five per cent of the workforce or less. What's more, many of the skills required to design, set-up or operate machinery or technological systems are declining in importance.

Figure 2. The essential talents in the UK's workforce

Rank 2015	Rank 2001		Talent
1	2	▲	 Oral comprehension
2	1	▼	 Problem sensitivity
3	3	–	 Oral expression
4	4	–	 Near vision
5	5	–	 Deductive reasoning
6	6	–	 Critical thinking
7	8	▲	 Speaking
8	7	▼	 Information ordering
9	10	▲	 Monitoring
10	9	▼	 Active listening
11	11	–	 Speech recognition
12	12	–	 Speech clarity
13	13	–	 Category flexibility
14	17	▲	 English language
15	16	▲	 Coordination
16	14	▼	 Inductive reasoning
17	15	▼	 Written comprehension
18	18	–	 Reading comprehension
19	19	–	 Social perceptiveness
20	21	▲	 Judgement and decision-making
21	20	▼	 Time management
22	23	▲	 Customer and personal service
23	22	▼	 Selective attention
24	24	–	 Written expression
25	25	–	 Complex problem-solving

Source: O*NET, ONS, Deloitte analysis



Knowledge



Skill



Ability

Category	Description
Cognitive	The ability to listen to and understand information and ideas presented through spoken words and sentences
Cognitive	The ability to tell when something is wrong or is likely to go wrong
Cognitive	The ability to communicate information and ideas by speaking so others will understand
Sensory	The ability to see details at close range
Cognitive	The ability to apply general rules to specific problems to produce answers that make sense
Process	Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems
Content	Talking to others to convey information effectively
Cognitive	The ability to arrange things or actions in a certain order or pattern according to a specific rule or set of rules
Process	Monitoring/assessing performance of yourself, other individuals or organisations to make improvements or take corrective action
Content	Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting
Sensory	The ability to identify and understand the speech of another person
Sensory	The ability to speak clearly so others can understand you
Cognitive	The ability to generate or use different sets of rules for combining or grouping things in different ways
Arts & humanities	Knowledge of the structure and content of the English language including the meaning and spelling of words, rules of composition and grammar
Social	Adjusting actions in relation to others' actions
Cognitive	The ability to combine pieces of information to form general rules or conclusions (includes finding a relationship among seemingly unrelated events)
Cognitive	The ability to read and understand information and ideas presented in writing
Content	Understanding written sentences and paragraphs in work-related documents
Social	Being aware of others' reactions and understanding why they react as they do
Systems	Considering the relative costs and benefits of potential actions to choose the most appropriate one
Resource management	Managing one's own time and the time of others
Business & management	Knowledge of principles and processes for providing customer and personal services
Cognitive	The ability to concentrate on a task over a period of time without being distracted
Cognitive	The ability to communicate information and ideas in writing so others will understand
Complex problem-solving	Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions

These issues present something of a challenge to policymakers and educators.

First, the UK has an education system that is designed primarily to help students acquire knowledge. For many subject areas, this knowledge is essential to enabling university graduates to enter careers in professional or associate professional and technical occupations – jobs in science, research, engineering, technology, health and social care, teaching, media and other business services that require a combination of specialist knowledge and high-skills. However, the academic knowledge that many students acquire during their school and university lives provides them with just a fraction of what they require in their longer careers. Instead, they need to acquire a more balanced scorecard of talents from their time in education, concentrating on essential cognitive, social, process, content and problem-solving skills and abilities, as well as knowledge, and learning how to apply these in relevant environments so they can become more employable.

Second, much of the commentary around the digital economy thus far has placed significant emphasis on the importance of ‘digital skills’ without being clear about precisely what this term means – or, indeed, whether there are other important ‘digital talents’ that are vital to the future economy. Coding is often cited now as an essential digital skill, yet our analysis shows that this is not of widespread importance to the workforce. However, computer code is often the manifestation of a combination of other skills, abilities and knowledge. For instance, successful algorithm design requires information ordering, inductive and deductive reasoning, category flexibility, written expression, complex problem-solving, judgement and many other cognitive skills and abilities. In other words, coding provides a means of acquiring essential talents but it is not itself an essential skill. We can make similar arguments about STEM. So this new research suggests that we might need to reframe what we mean by ‘digital skills’. And perhaps even how our conventional thinking on science, technology, engineering and mathematics should shift to focus more on the underlying skills, strategies and methods than on academic excellence.

How will technology and automation impact these essential skills? Well, there is no doubt that technologies like Natural Language Processing and machine learning are increasingly capable of performing a narrow range of routine tasks involving reading comprehension, speech recognition, speaking and inductive reasoning, for instance. But many of the skills and abilities listed in Figure 2 are also vital for non-routine work and especially for activities involving interaction with other people. We also know from previous Deloitte work that technology’s impact on the UK workplace has been largely positive. While technology has contributed to the loss of around 800,000 British jobs, it has helped create 3.5 million new ones. Interestingly, our new analysis suggests that despite the employment flux, the fundamental human talents required by the UK economy have stayed largely constant. Across the full spectrum of talents, some notable changes are in the relative declines in the utility of physical and psychomotor abilities, which do not make our top 25, in favour of increases in the need for English language, and negotiation and persuasion skills, for instance. The increase by five percentage points in the proportion of workers for whom negotiation skills are important, equates to nearly 1.4 million jobs. This demonstrates that despite the inroads made by digital and other smart technologies into the workplace, the essential human talents highlighted in our work will be ones that remain important to the UK workforce.

We have also estimated which skill, ability or knowledge domain has the highest absolute score of importance based on total employment in each occupation. This process reveals the top ten most and least important characteristics in the UK's workforce in 2015, which are shown in Figure 3.

The top-ten list of most important attributes is dominated by cognitive abilities, which influence the acquisition and application of knowledge in problem-solving, and content skills, which include the background structures needed to work with and acquire more specific skills in a variety of different domains. Customer and personal service knowledge includes knowledge of principles and processes for providing customer and personal services, such as customer needs assessment, meeting quality standards for services and evaluation of customer satisfaction. In other words, the list of most important attributes includes the fundamental skills, knowledge and abilities that workers require to interact with, understand and communicate with other people.

By contrast, the top-ten list of least important attributes incorporates a range of physical and sensory skills and abilities that are being used less frequently in a range of repetitive manual tasks best-suited to machines. For human workers, the ability to listen to and understand information and ideas presented by other people is deemed to be five times more important than explosive strength.

The workforce in 2030

The mix of skills, knowledge and abilities is not constant. As employment levels in different occupations vary over time, so too do the characteristics of the workforce overall. If we assume that the shifts in the importance of worker qualities that occur in the actual data for 2001-15 continue to persist for the next 15 years, by 2030 we forecast that millions of new jobs will be required, each demanding stronger cognitive abilities, content and process skills, or more specialist knowledge than currently.

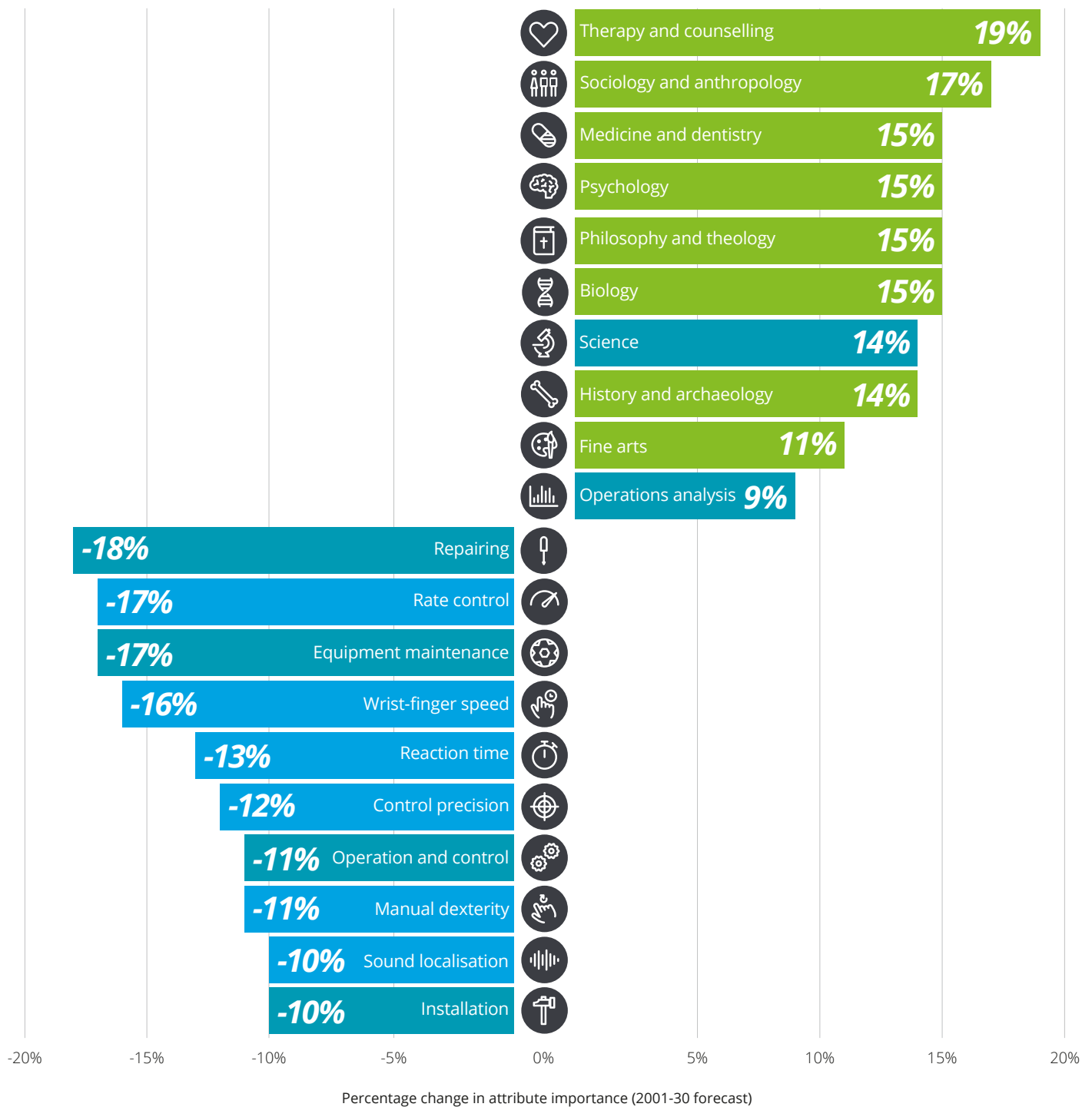
For example, we forecast that the importance of using scientific rules and methods to solve problems will increase by 14 per cent between 2001 and 2030, whereas the importance of performing routine maintenance on equipment will decline by approximately 17 per cent. Figure 4 shows the fastest growing and fastest shrinking attributes in terms of their importance.

Figure 3. Top ten most and least important talents in the UK's workforce in 2015

Most important attributes	Least important attributes
1. Customer and personal service knowledge	111. Food production knowledge
2. Oral comprehension (ability)	112. Repairing skills
3. Oral expression (ability)	113. Fine arts knowledge
4. English language knowledge	114. Glare sensitivity (ability)
5. Active listening skills	115. Sound localisation (ability)
6. Written comprehension (ability)	116. Peripheral vision (ability)
7. Problem sensitivity (ability)	117. Night vision (ability)
8. Speaking skills	118. Explosive strength (ability)
9. Near-vision (ability)	119. Installation skills
10. Critical thinking skills	120. Dynamic flexibility (ability)

Source: O*NET, ONS, Deloitte analysis

Figure 4. Top ten fastest growing and fastest declining attributes in the UK's workforce



Source: O*NET, ONS, Deloitte analysis

The rise in importance of knowledge over this 30-year period may come as a surprise to some people. However, many of the fastest growing knowledge domains in Figure 4, which include a number of STEM attributes, can be linked to their application in health and social care occupations, which have already added over one million jobs since 2001. Attributes that can be more readily associated with tasks performed by machines are suffering the greatest falls in importance as the occupational mix shifts towards more cognitive and social domains.

Let's put the magnitude of these increases into perspective. If we assume that the forecast 7.9 per cent increase in the importance of mathematics and science knowledge is met by recruiting more workers in professional occupations (the major SOC group for which this specialist knowledge is most important) then we would need to add approximately 4,500,000 new jobs to meet this demand, more than doubling the current levels of employment. The same is true for all of the attributes that are increasing in importance: the effect is a massive increase in demand for appropriately qualified workers, as illustrated in Figure 5.

Figure 5. Five scenarios for 2030

Attributes in demand	Percentage change	Which major SOC group ranks this attribute as most important?	Number of additional workers needed to meet demand
Health services knowledge	17.4%	Professional occupations	6,500,000
Mathematics and science knowledge	7.9%	Professional occupations	4,500,000
Systems skills	6.1%	Professional occupations	4,800,000
Process skills	4.7%	Professional occupations	5,500,000
Social skills	4.6%	Professional occupations	8,900,000

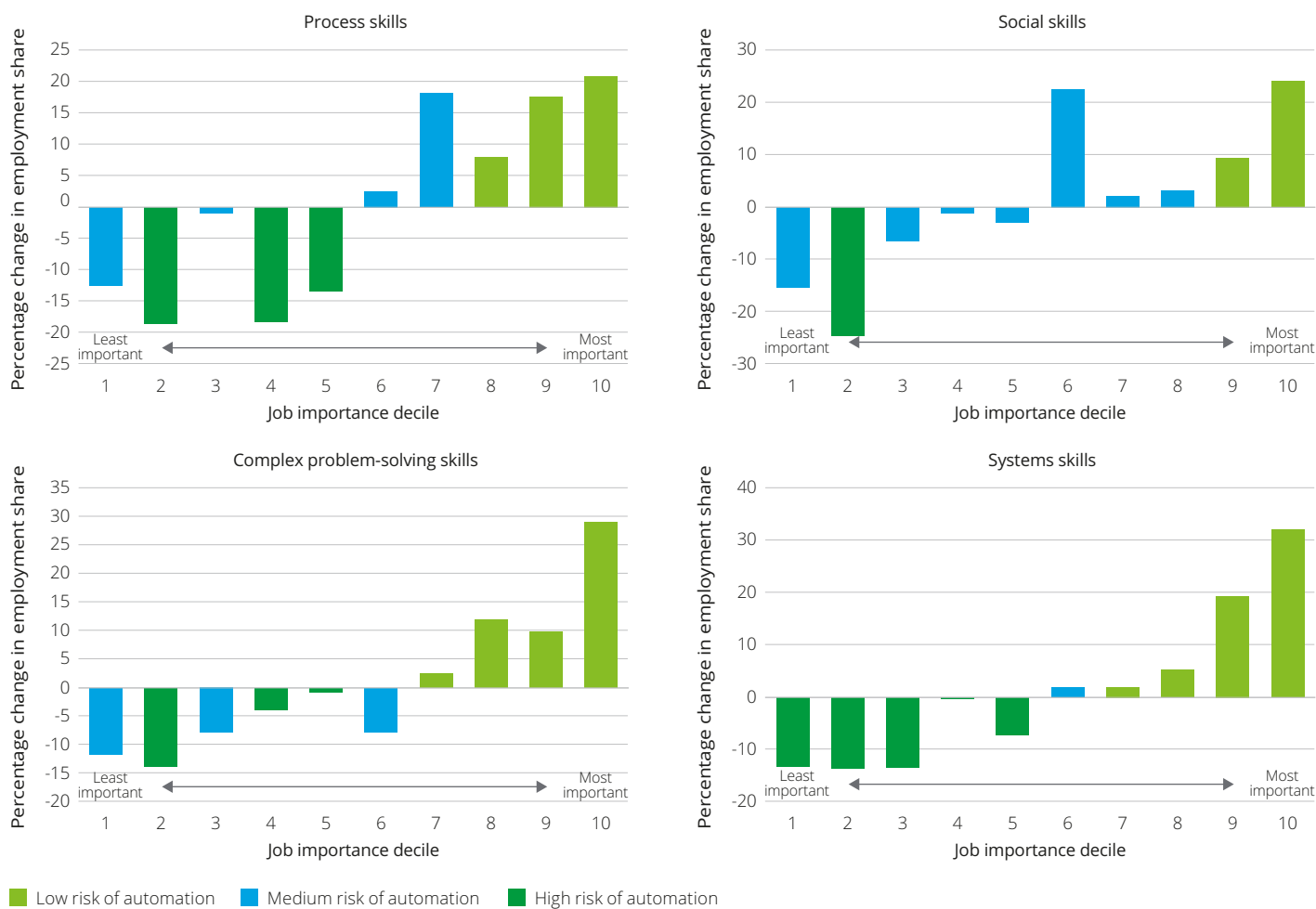
Source: O*NET, ONS, Deloitte analysis

Understanding the current mix

If we rank UK jobs in order of the importance of each attribute, we can see more clearly how different skills, knowledge and abilities have potentially contributed to changes in employment. In Figure 6, we show four high-level skills – process skills, social skills, complex problem-solving skills and systems skills – that have a positive relationship with employment share. In each case, increasing importance of the attribute is correlated with an increase in employment share during the last 15 years. The charts also use different

colours to indicate the risk of automation at each level of importance, based on the analysis performed by Michael Osborne and Carl Benedikt Frey for Deloitte in 2014.¹⁹ What becomes abundantly clear from Figure 6 is that jobs at the lowest risk of automation are also deemed to have the highest levels of importance of these skills.

Figure 6. Worker qualities with a positive effect on employment share



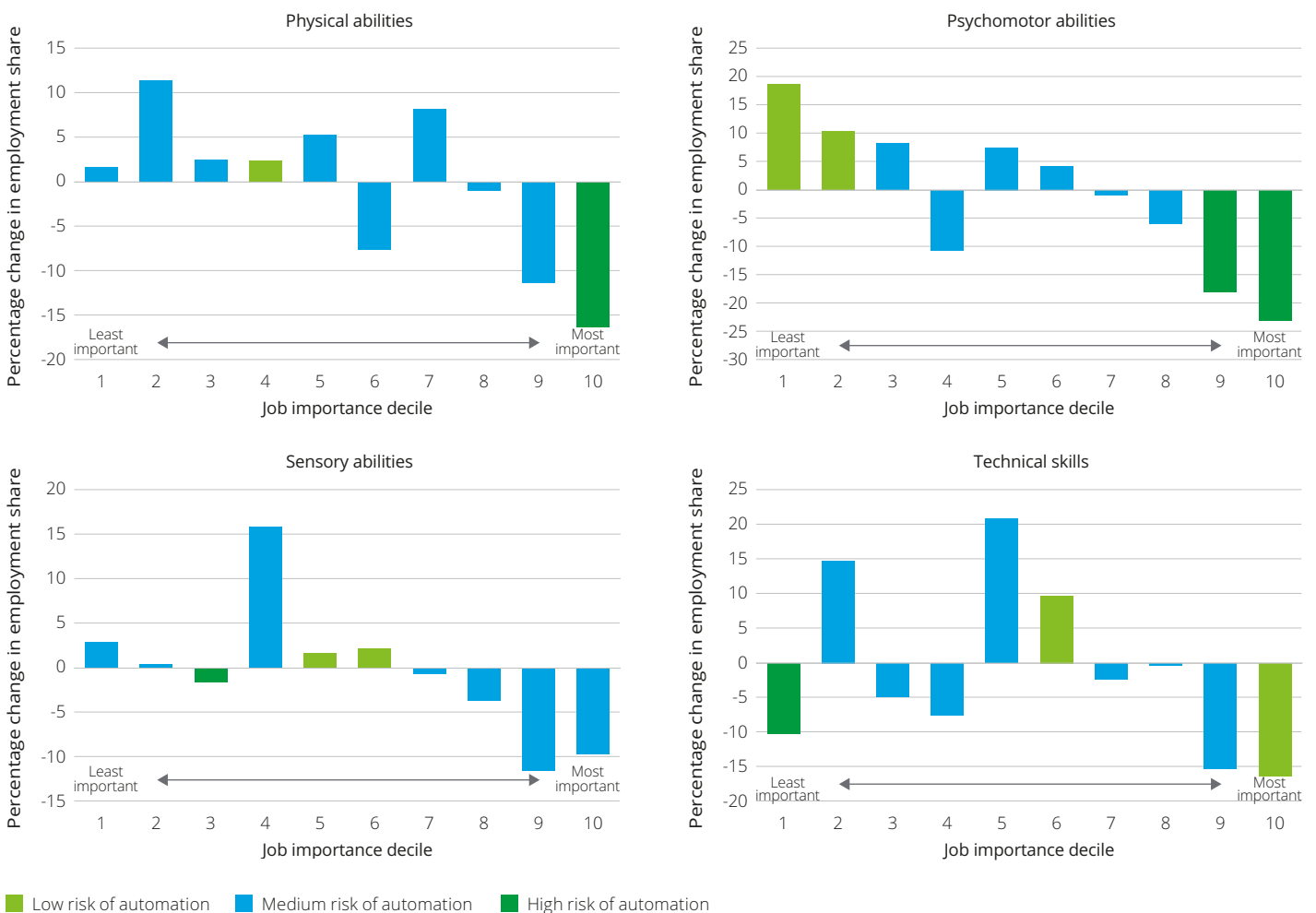
Source: O*NET, ONS, Deloitte analysis

Figure 7 shows four characteristics – physical abilities, psychomotor abilities, sensory abilities and technical skills – that have a negative relationship with employment share. In other words, jobs in which the ability is deemed to have highest importance are correlated with a decline in employment share since 2001.

Physical abilities include physical strength, endurance, flexibility, stamina and coordination; psychomotor abilities relate to dexterity, precision and fine-motor control, and the ability to make fast, simple, repeated movements of the fingers, hands and wrists – all abilities in which robots are improving or becoming able to perform as well as or better than humans.

Perhaps the most impactful illustration of robots taking over physical tasks that require these abilities and skills comes from the May 2016 announcement by Foxconn, the Chinese manufacturing giant, that it had replaced as many as 60,000 workers at its Kushan facility by robots.²⁰ In a statement, the company said, “We are applying robotics engineering and other innovative manufacturing technologies to replace repetitive tasks previously done by employees.” However, the company also said that it was investing in training to enable its remaining employees to focus on higher value-added elements in the manufacturing process, such as research and development, process control and quality control – elements that require higher levels of cognitive ability and skills, as well as related knowledge.

Figure 7. Worker qualities with a negative effect on employment share



Source: O*NET, ONS, Deloitte analysis

In this example, human workers are moving up the value chain, contributing to greater productivity overall.

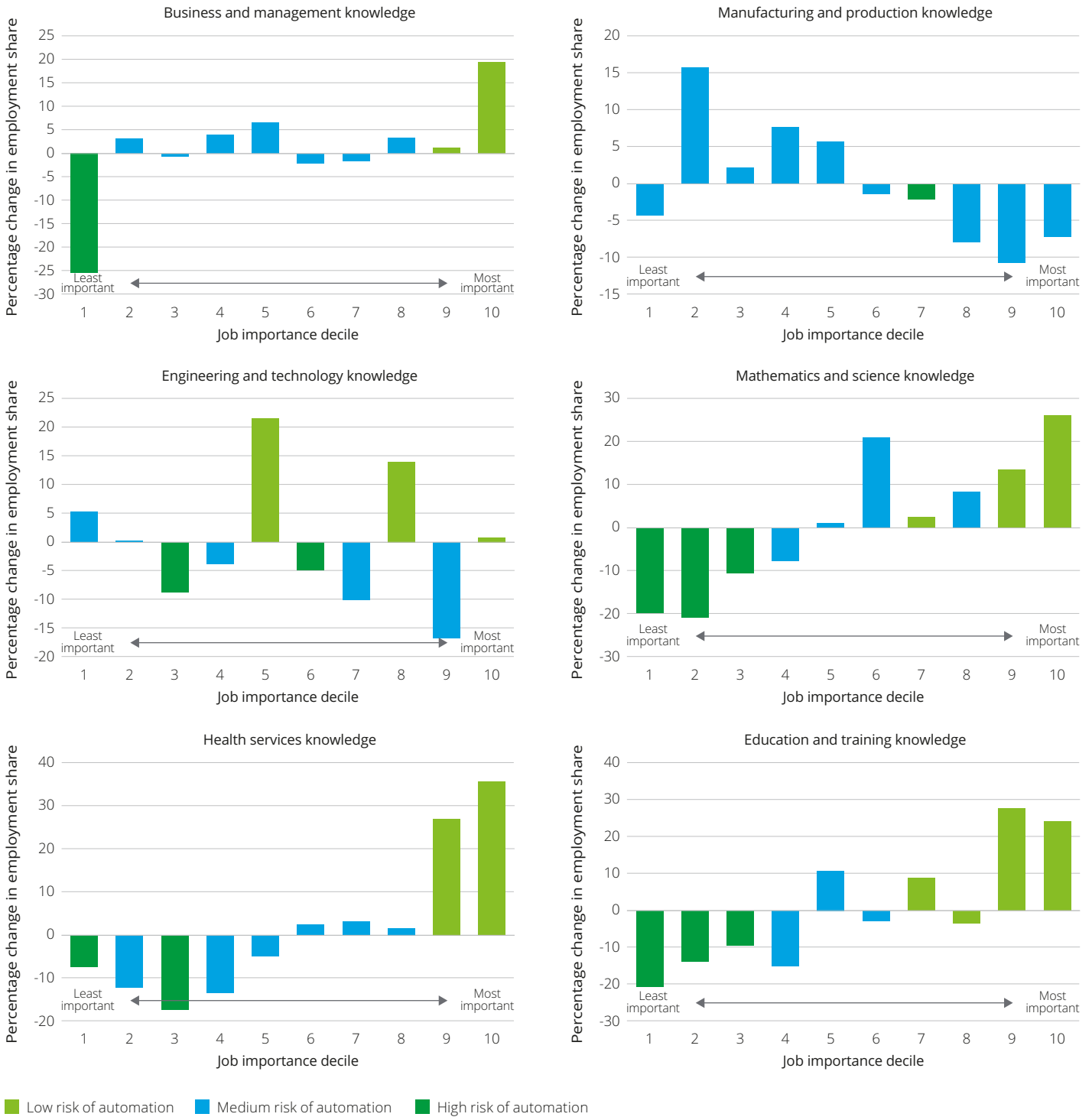
The gigantic baggage handling systems at Dubai's international airport – the world's largest such system – also demonstrates how robots are remixing workforce skills. In 2015, the airport handled 78 million passengers.²¹ Its 17 kilometres of conveyor belts, 46 kilometres of high-speed sorting systems and 800 Radio Frequency Identification (RFID) read/write stations can automatically sort 15,000 pieces of luggage every hour.²² Yet the entire operation is managed by a team of just 400 IT and maintenance specialists using sophisticated software.

Figure 8 shows the relationship between six different domains of knowledge and changes in employment share. In occupations where knowledge is very important, it is apparent that employment share is typically increasing, although not all knowledge, including some STEM knowledge, contributes to employment gains. For instance, as the importance of engineering and technology knowledge increases, employment share for occupations requiring this level of knowledge actually decreases.

The strongest positive correlation with employment share occurs in the domains of mathematics and science, health services, and education and training. Occupations in which mathematics and science knowledge is of highest importance have increased their share of total employment by over 26 per cent between 2001 and 2015; and occupations in which health services knowledge is of highest importance, by over 33 per cent. By contrast, occupations in which mathematics and science knowledge are of lowest importance have declined as a share of total employment by nearly 20 per cent.

For occupations in which the importance of mathematics and science knowledge, education and training knowledge, or arts and humanities ranks them in the tenth decile, the risk of automation in the next 10 to 20 years is only five per cent or lower.

Figure 8. The effect of knowledge on employment share






Source: O*NET, ONS, Deloitte analysis

The link between skills and earnings

As Andrew McAfee, co-author of “The Second Machine Age”, has observed, many of the jobs that machines cannot do today do not pay very well.²³ This means that even though certain skills, knowledge and abilities are ‘machine-proof’, increasing in importance and contributing towards a greater share of overall employment in the UK, they are not all valued equally.

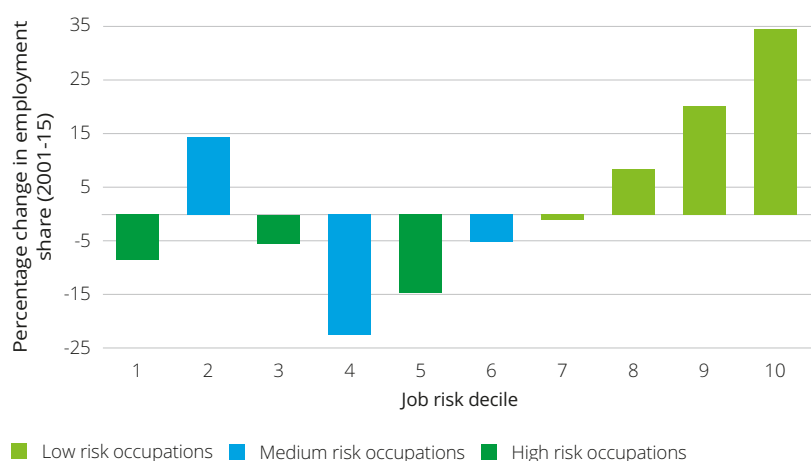
Using revised data from the 2014 Annual Survey of Hours and Earnings (ASHE), provided by the ONS, we have undertaken multiple regression analysis to determine the relationship between key worker attributes and median hourly earnings. Figure 9 shows the impact on earnings of changes in high-level skills, knowledge and abilities.

Figure 9. The impact of high-level skills, knowledge and abilities on median hourly earnings

Domain	Attribute	Percentage increase in hourly earnings for a ten per cent increase in attribute*
 Skills	Social skills	10.06%
	Technical skills	1.56%
	Content skills	-1.95%
	Process skills	-2.69%
	Resource management skills	-3.03%
	Systems skills	-8.10%
	Complex problem-solving skills	-9.22%
 Knowledge	Business and management	2.15%
	Manufacturing and production	1.29%
	Mathematics and science	0.81%
	Education and training	0.58%
	Arts and humanities	0.46%
	Transportation	-0.36%
	Law and public safety	-0.68%
	Communications	-1.03%
	Health services	-1.99%
	Engineering and technology	-2.05%
 Abilities	Cognitive abilities	12.06%
	Psychomotor abilities	-0.23%
	Sensory abilities	-1.23%
	Physical abilities	-2.05%

* All other factors remaining constant

Source: O*NET, ONS, Deloitte analysis, based on multiple regression using 21 attributes across 359 occupations for which earnings data was available, giving $R^2 = 0.56$

Figure 10. The hollowing-out of the UK's economy

Each job quality decile represents approximately ten per cent of the workforce, in which occupations are ordered by average yearly earnings.

Source: ONS, Deloitte analysis (2015)

From Figure 9, we can observe that cognitive abilities, social skills and business and management knowledge contribute most to earnings. However, despite their importance from an employment perspective, a number of other cognitive skills and knowledge domains, including some associated with STEM, are keeping workers' incomes low. This is worrying economists and policymakers because, left unchecked, these disparities can lead to a 'hollowing-out' of the workforce, in which jobs most immune to automation only appear at opposite ends of the earnings spectrum.

As discussed in our report, "From brawn to brains: The impact of technology on jobs in the UK", economists Maarten Goos and Alan Manning developed a hypothesis for this hollowing-out, which suggests that routine cognitive jobs that require precision, such as book-keeping, are not typically performed by the lowest-skilled members of the workforce.²⁴ But they are increasingly automatable, in particular through rapid advances in technologies such as big data and machine learning. Figure 10, taken from our previous report, shows the hollowing-out that has occurred in the UK's economy over the last 15 years.

The relationship between cognitive abilities, social skills and earnings cannot be overstated. In a 2013 blog post, Forbes contributing writer George Anders described his analysis of job postings on Indeed.com, one of the world's largest job hunting sites.²⁵ He discovered around 1,000 vacancies that called for soft skills, such as "empathy", "good listener", "emotional intelligence" or "rapport" – all of which earned more than \$100,000 per annum.

Anders's list included postings from well-known global corporate "heavyweights" in the technology, food production, financial services, consulting, defence and life sciences sectors. Why do such employers care about these skills? His argument was that, "The fate of complex projects depends on a lot more than just getting the technical details right."

Empathy – a cognitive and emotional understanding of others' experiences – also affects commercial success. According to the *Harvard Business Review*, the top ten companies in the Global Empathy Index 2015 increased in value more than twice as much as the bottom ten and generated ten per cent more earnings.²⁶ Unfortunately, 16 of the bottom 25 firms are large listed British companies.

Shifts in industry sectors

“Should we not be somewhat surprised that technological change hasn’t already wiped out employment for the vast majority of workers? Why doesn’t automation necessarily reduce aggregate employment, even as it demonstrably reduces labour requirements per unit of output produced?”





David Autor²⁷

In their January 2016 report, “The Future of Jobs”, the World Economic Forum acknowledges that, “The accelerating pace of technological, demographic and socioeconomic disruption is transforming industries and business models, changing the skills that employers need and shortening the shelf-life of employees’ existing skills sets in the process.”²⁸ They join the likes of Autor, Brynjolfsson and McAfee, Davenport and Kirby, and Osborne and Frey in arguing that technological disruptions such as robotics, big data and machine learning – rather than completely replacing existing occupations – are likely to substitute for specific routine manual and cognitive tasks. This will free up workers to spend time on new tasks, drawing on their cognitive abilities, social skills and specialist knowledge, which machines cannot easily replicate. The consequences of this ‘division of labour’ are that the workforce becomes more productive and individual workers more effective. And even in occupations where tasks are ultimately automated, employment can still grow.

The effects are different, though, for different sectors of the economy because each requires a different mix of skills, knowledge and abilities. Figure 11 considers the top-level skills, knowledge and abilities and shows the sectors for which they are most and least important.

In general, cognitive abilities such as oral comprehension and oral expression are consistently among the most important attributes for every sector. Sectors with large numbers of customer-, citizen- or client-facing occupations also require high levels of customer and personal service knowledge. And there is – somewhat obviously – a strong correlation between sector-specific knowledge and its importance to that sector. Even where there might be an expectation that STEM skills and knowledge might be important to a sector such as information and communications, or professional, scientific and technical activities, cognitive abilities and process skills tend to be ranked as more important.

Figure 11. The importance of skills, knowledge and abilities by industry sector

Domain	Attribute	Most important for	Number of standard deviations from the mean	Least important for	Number of standard deviations from the mean
 Basic skills	Content skills	Professional, scientific and technical	1.45	Activities of households	-1.64
	Process skills	Education	2.29	Agriculture, Forestry & Fishing	-1.87
 Cross-functional skills	Social skills	Education	1.93	Agriculture, Forestry & Fishing	-2.12
	Technical skills	Manufacturing	1.53	Financial and insurance	-1.38
	Resource management skills	Information and communications	1.83	Administrative and support services	-1.54
	Systems skills	Information and communications	1.91	Activities of households	-1.50
	Complex problem-solving skills	Information and communications	1.94	Agriculture, Forestry & Fishing	-1.79
 Knowledge	Business and management	Financial and insurance	2.33	Agriculture, Forestry & Fishing	-1.53
	Manufacturing and production	Accommodation and food services	2.84	Education	-0.98
	Mathematics and science	Education	2.75	Transportation and storage	-1.34
	Education and training	Education	3.65	Transportation and storage	-1.31
	Arts and humanities	Education	3.29	Agriculture, Forestry & Fishing	-1.51
	Transportation	Transportation and storage	2.91	Information and communications	-1.07
	Law and public safety	Public administration and defence	1.99	Information and communications	-1.46
	Communications	Information and communications	2.91	Agriculture, Forestry & Fishing	-2.16
	Health services	Human health and social work	3.50	Information and communications	-0.80
	Engineering and technology	Construction	2.58	Human health and social work	-1.29
 Abilities	Cognitive abilities	Information and communications	1.55	Agriculture, Forestry & Fishing	-2.18
	Psychomotor abilities	Transportation and storage	1.60	Financial and insurance	-1.65
	Sensory abilities	Transportation and storage	2.38	Financial and insurance	-1.73
	Physical abilities	Activities of households	2.04	Financial and insurance	-1.63

Source: Deloitte analysis

From brawn to brains, and the importance of social skills

Our analysis also reveals the extent to which different sectors rely upon cognitive abilities (brains) rather than physical ones (brawn). Figure 12 shows that cognitive abilities are nearly four times more important to the information and communications, and financial services sectors than physical abilities.

Social skills are also consistently rated as more important than technical skills, as Figure 13 shows, particularly for workers in the public sector and retail businesses.

Figure 12. From brawn to brains

Industry sector	Total employment in 2015 (nearest 10,000)	Percentage of jobs at high risk of automation	Ratio of the importance of cognitive to physical abilities
Information and communications	1,260,000	15%	3.96
Financial and insurance	1,190,000	42%	3.91
Professional, scientific and technical	2,090,000	29%	3.65
Activities of extraterritorial organisations	30,000	31%	3.04
Real estate	350,000	24%	2.94
Electricity, gas, steam and air conditioning supply	190,000	30%	2.60
Education	3,240,000	14%	2.57
Public administration and defence	1,770,000	30%	2.50
Mining and quarrying	130,000	30%	2.35
Other services	830,000	21%	2.09
Arts, entertainment and recreation	810,000	28%	2.00
Water supply, sewerage and waste management	230,000	42%	1.94
Manufacturing	3,030,000	46%	1.91
Human health and social work	4,180,000	16%	1.88
Wholesale and retail trade	4,060,000	59%	1.85
Construction	2,280,000	42%	1.73
Administrative and support services	1,450,000	34%	1.73
Transportation and storage	1,530,000	63%	1.65
Agriculture, Forestry and Fishing	350,000	36%	1.51
Accommodation and food services	1,680,000	59%	1.48
Activities of households as employers	70,000	19%	1.28

Source: ONS, Deloitte analysis

Figure 13. EQ versus IQ

Industry sector	Total employment in 2015 (nearest 10,000)	Percentage of jobs at high risk of automation	Ratio of the importance of social to technical skills
Education	3,240,000	14%	2.80
Financial and insurance	1,190,000	42%	2.76
Human health and social work	4,180,000	16%	2.67
Real estate	350,000	24%	2.62
Public administration and defence	1,770,000	30%	2.48
Arts entertainment and recreation	810,000	28%	2.43
Activities of extraterritorial organisations	30,000	31%	2.40
Wholesale and retail trade	4,060,000	59%	2.34
Accommodation and food services	1,680,000	59%	2.34
Professional scientific and technical	2,090,000	29%	2.30
Other services	830,000	21%	2.24
Administrative and support services	1,450,000	34%	2.15
Activities of households as employers	70,000	19%	2.06
Information and communication	1,260,000	15%	1.83
Electricity gas steam and air conditioning supply	190,000	30%	1.81
Transportation and storage	1,530,000	63%	1.72
Water supply sewerage waste management	230,000	42%	1.66
Mining and Quarrying	130,000	30%	1.64
Construction	2,280,000	42%	1.57
Agriculture Forestry and Fishing	350,000	36%	1.53
Manufacturing	3,030,000	46%	1.51

Source: ONS, Deloitte analysis

Challenges yet to be overcome

“In such a rapidly evolving employment landscape, the ability to anticipate and prepare for future skills requirements, job content and the aggregate effect on employment is increasingly critical for businesses, governments and individuals in order to fully seize the opportunities presented by these trends.”

World Economic Forum²⁹

Technology advancement undoubtedly delivers benefits to individuals and organisations. But as the capabilities of robotics, big data, artificial intelligence and other ‘smart’ technologies continue to accelerate, policymakers, educational institutions, public sector organisations and businesses in all industry sectors will face an increasingly complex and difficult array of issues.

Policy makers

The challenges for government include:

- **What are the appropriate levels of investment in education?** The UK has one of the highest proportions of university-level graduates in its workforce of any major economy in the world. As Figure 14 demonstrates, higher levels of investment are linked to lower levels of risk that jobs will be replaced by machines. With the workforce mix changing, how much will need to be invested in the next generation of workers to ensure that they have the appropriate levels of skills, knowledge and ability?
- **How can education and skills development reach everyone?** Students from low-income backgrounds are less likely to study STEM subjects and employers report that they are not as fluent in some of the cognitive and basic skills and abilities as those from more affluent backgrounds.³⁰ How can participation from people in these and other disadvantaged communities, such as women or military veterans, be increased?

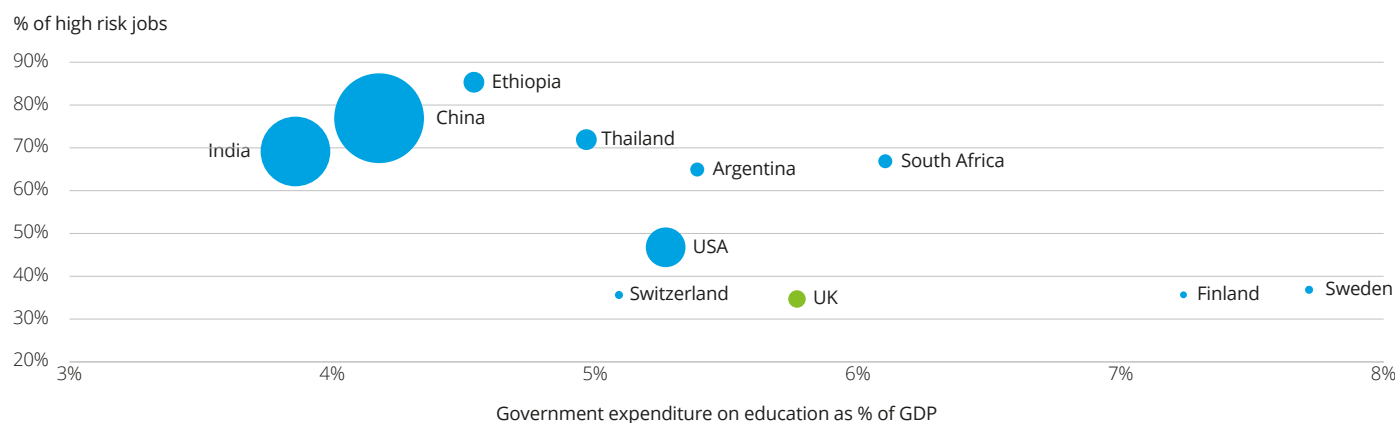
- **How can hollowing-out be avoided?** While some have talked about the need for a universal basic income to mitigate the effects of increasing technological unemployment, others have suggested tax credits for low-income workers or tax breaks for businesses and other organisations seeking to upskill their employees. But should governments simply fund the growing deficit? Or should they adopt a more active approach to encourage workers to retrain.

- **What measurements can we make to ensure we’re getting it right?** Although the acquisition and recall of knowledge can be tested through conventional exams, what methods can be put in place to assess the cognitive and social skills and abilities of both students and workers? What are the targets that we should aim for?

Educators

The challenges for our schools, colleges and universities include:

- **What should tomorrow’s national curriculum include?** As workforce requirements shift towards a blend of cognitive abilities, specialist knowledge and content, and process and social skills, what should we be teaching our children today so that they are ready to enter the workforce in 2030?
- **How early should we teach these skills and knowledge?** Young children are naturally inquisitive and it may be easier to develop strong cognitive skills and abilities early rather than waiting until further or higher education. What methods can we use with young children to give them the tools they need for 2030?

Figure 14. Risk of job automation vs government expenditure on education

Area of bubbles is proportional to total employment in 2015

Source: World Bank, Frey/Osborne, Citigroup, MOE China, Deloitte analysis

- **How can cognitive abilities and social skills be taught, or must they simply be learned?** While education has conventionally been aimed at ensuring students can acquire and access relevant knowledge, it is much more difficult to teach soft skills and cognitive abilities. How should educators adapt? And what resources can they use to help students acquire these new skills?
- **What can parents and other influencers do to help children?** How should parents and guardians be educated around the changing nature of work so that they can advise and support their children? What role should businesses play in education, through volunteering and the support they provide to schools, colleges and universities?
- **Who will teach the teachers?** With the current shortages of teachers, how can schools, colleges and universities find, recruit and develop teachers so that they can develop the required skills, knowledge and abilities in their pupils and students?

Businesses

The challenges for businesses include:

- **What training and development programmes should be implemented?** If some of the most important skills have to be learned and cannot be taught, how should training and development programmes be reconfigured? Will on-the-job learning become more important than classroom-based activities?
- **What skills, knowledge and abilities should be recognised when recruiting new workers?** A First Class degree from Oxford or Cambridge universities or excellent exam grades are a sign that an individual has acquired and is able to access knowledge. But how should cognitive and social abilities and skills be recognised during the recruitment process? And should they be considered as equal to a degree from a top-ranked university? Should more emphasis be placed on measuring potential by understanding how people respond in certain situations? What are the methods we can use for measuring such potential?

Our conclusion – get the mix right

“There’s never been a better time to be a worker with special skills or the right education, because these people can use technology to create and capture value. However, there’s never been a worse time to be a worker with only ‘ordinary’ skills and abilities to offer, because computers, robots, and other digital technologies are acquiring these skills and abilities at an extraordinary rate.”

Erik Brynjolfsson, Andrew McAfee³¹

Deloitte’s new research points towards a fundamental shift in the balance of skills, knowledge and abilities in the UK’s workforce as organisations adapt their operations to suit an increasingly global and digital world. This remixing of the economy is positive for organisations that are able to harness technologies like robotics, big data and artificial intelligence to automate routine and increasingly non-routine tasks, thereby improving efficiency and effectiveness, gaining competitive advantage or making smarter, faster decisions. It is also positive for organisations whose workers have the general-purpose skills and abilities needed to work alongside the machines, augmenting their intelligence and capabilities so that they can do more and be more than their counterparts from previous generations. And finally, the remixing favours workers whose unique blend of specialist skills and knowledge is unlikely to make their jobs the target of automation in the near future.

Organisations, big or small, that are not able to adapt to this new era of automation are likely to struggle. Although their workforces may have scale, brawn or deep technical skills, they are unlikely to be able to compete against the might of the machines or organisations with a workforce with more adaptable skills. For individual workers and job seekers, their survival may appear uncertain. On the one hand, ‘techno-pessimists’ argue that millions of jobs will be lost to smart computers and robots, citing a growing list of examples demonstrating that in some industries large-scale layoffs are indeed happening. On the other hand, optimists point to the automation of discrete tasks, not whole occupations, and the continued technology-driven expansion of the workforce.

However, our new research suggests that there are clear and substantive grounds for optimism. In the long-run, technology is creating more jobs than it is destroying. But we have found that although STEM skills and knowledge are in demand, they are not as important as having a blend of strong foundational and general purpose skills and abilities – cognitive abilities, and content, process and social skills, especially. And while a little knowledge can be a very bad thing in terms of employment prospects, deep specialist knowledge in a range of domains has been shown to increase the share of employment for numerous occupations. The UK’s economy is also under increasing pressure from a hollowing-out of the workforce. Although its effects have not yet fully materialised, middle-income, middle-skills jobs are under considerable threat of being replaced by ever-more capable robots, software automation and other rapidly advancing technologies.

It is impossible to predict accurately the make-up of the economy in 2030. But, if current trends persist – and if we can find sufficient numbers of highly skilled, capable and knowledgeable workers – then many occupations in the future will be performed by a composite of people and machines. The people will be responsible for the vital human aspects of the role, while the machines carry out the repetitive, manual, logical and quantitative aspects. But this vision presupposes that we can educate, train, recruit and retain a new cadre of highly adaptable workers, and reskill existing generations, so that they can flourish and, as Thomas Davenport suggests, be “augmented”.³²

And although the UK's economy does not look set to be as badly disrupted by automation as, say, China's or the US's, there are no grounds for complacency.

The reality is that no matter the perceived or actual level of risk, unless the mix of skills, knowledge and abilities is right, it will become increasingly difficult to sustain growth, and the UK's influence as a major economy will decline.

Tom Watson MP has said, "We need government, workers, employers and enlightened entrepreneurs to work in partnership to ensure everyone gains from the benefits these changes will bring."³³ There is no question that there are challenges for policymakers and educators, as well as for businesses and individual workers, themselves. This recent study highlights a number of issues and reinforces the need for further discussion and swift action.

And as Andrew McAfee observed recently, "We need to keep in mind that this is a situation brought about by the fact that technology is letting us do and create much more with much less drudgery and toil. If we cannot figure out how to deal with this, and how to make sure that the fruits of robots' labour are shared in a way that reflects our shared values and protects our most vulnerable, then shame on us. In that case, we will have met the real foe, and it will be us."³⁴ Getting the workforce mix right and getting the most from what technology promises to deliver will set the stage for the UK's long-term economic success. It will also lead to an economy in which the outputs are, perhaps, more quintessentially human than they have ever been.

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Designed and produced by The Creative Studio at Deloitte, London. J7849