

LEARNING TO LEARN

THE FUTURE-PROOF SKILL



**BIG
INNOVATION
CENTRE**



All Party Parliamentary Group on
Artificial Intelligence



A report created by **Big Innovation Centre**, the Secretariat for the **All-Party Parliamentary Group on AI**, and powered by **KPMG**.

With **Contributions** by:

Professor Birgitte Andersen, Big Innovation Centre
Lord Clement-Jones, APPG AI
Stephen Metcalfe MP, APPG AI
Robert Bolton, KPMG
Martin Anderson, KPMG
Sir Anthony Seldon, University of Buckingham
Professor Rose Luckin, University College London
Professor Margaret Boden, University of Sussex
Professor Joanna Bryson, University of Bath
Dr. Andreas Theodorou, University of Bath
Professor Jonathan Seville, Royal Academy of Engineering
Jonnie Penn, University of Cambridge
Kevin Green, Recruitment & Employment Confederation
Tess Posner, AI4All

Written by: Niki Iliadis | Email: n.iliadis@biginnovationcentre.com

www.biginnovationcentre.com | @BigInnovCentre
www.appg-ai.org | @APPG_AI

© Big Innovation Centre 2018. All rights reserved.

CONTENTS

FOREWORDS

- 4** APPG AI
- 5** Big Innovation Centre
- 6** KPMG

8 SNAPSHOT

I. SETTING THE SCENE

- 12** What is AI?
- 13** Why now?
- 13** Who will AI impact?
- 14** What are some key implications?

II. AI AND SKILLS

- 16** How AI is transforming labour?
- 19** Kevin Green: The Modern Labour Market
- 20** What is the impact of AI on skills?
- 23** Prof. Margaret Boden: Making, Using, and Living with AI
- 25** Why hard skills?
- 27** Prof. Jonathan Seville: Engineering Habits of Mind
- 28** Why soft skills?
- 29** Jonnie Penn: Three Varieties of Intelligence
- 31** Is hard vs. soft a false dichotomy?
- 31** Robert Bolton: Dilemma Reconciliation

III. SKILLS VIA AI

- 34** How do we develop skills?
- 37** How to upskill the classroom?
- 37** Tess Posner: A New Approach to Empowering the Future
- 38** Prof. Joanna Bryson & Dr. Andreas Theodorou: AI Ethics Courses
- 40** Prof. Rose Luckin: The Potential of AI in Education
- 41** How to upskill the workplace?
- 44** Robert Bolton: The Reinvention of Work

IV. THE ROAD AHEAD

- 50** Why learning to learn?
- 53** Martin Anderson: Transforming L&D Function
- 55** Sir Anthony Seldon: Education, AI's Cinderella Area

57 ACKNOWLEDGEMENTS

58 REFERENCES

FOREWORD

WELCOME FROM APPG AI



LORD TIM CLEMENT-JONES

APPG AI CHAIR

For young and old the crucial question, as professions and sectors increasingly adopt artificial intelligence in the delivery of their goods and services, is not only what the jobs of the future will look like but what skills will be needed to carry them out.

As this report convincingly describes these will be the skills needed to work and live alongside AI. They will not just be the harder skills of computer science, maths and data analytics, but softer skills will be essential too: critical thinking and problem solving, collaboration and creative skills, such as curiosity and imagination.

This major piece of work will, I hope, serve as an essential guide for those looking to adapt to the future of work but also for policymakers and the learning and development profession who need to restructure our education and training system so that it can develop and deliver these skills.



STEPHEN METCALFE MP

APPG AI CHAIR

AI is a technology that is transforming every walk of life. On the one hand, the opportunities it offers are key for our nation's growth and our citizens' wellbeing. And, on the other, its associated risks introduce a new set of challenges we must urgently respond to.

This is far from an easy task – and, more than ever, will require the collaboration of policymakers, industry, academia, and civic society. We must prepare and empower ourselves with the skills we will need to survive and thrive.

This report touches the heart of this very issue – unpacking how AI is transforming the skills we will need as 21st century workers and, even more so, as 21st century citizens.

Realising that the report's recommendations are only as powerful as their implementation, I urge policymakers, educators, employers, and the broader society to commit and take action.

FOREWORD

WELCOME FROM BIG INNOVATION CENTRE



PROFESSOR BIRGITTE ANDERSEN

CEO, BIG INNOVATION
CENTRE

The office is outdated, costly to run, and underperforming. No workforce can hang on to jobs when this is happening. Media, music, book and newspaper publishing were the first to face the digital revolution. Now manufacturing is confronted with automation and robotics. The next economic sector to be disrupted will be the automation of professional and public services, and regular, routine office work in companies. The professional office is already being impacted by adopting micro-electronics into existing business processes.

Sixty per cent of our jobs will not exist or will be done in totally new ways over the coming 10 years, but how will they look? Are we now moving towards the 'science fiction' vision of AI, promising a world where computers and robots will emulate the human brain to perform any intellectual tasks without a human touch?

As we see in this report, the majority of AI currently being implemented fit a more narrow category, where we will need learning to learn skills interacting with software programmes at work or at home as AI overtakes specific tasks of our daily routines.

This report brings together thought leadership on how we can future proof our skills to live more happy with more meaningful and sustainable lives, as bespoke, almost craft-based professional tasks are being standardized and systematised with AI.

FOREWORD

WELCOME FROM KPMG

“It’s hard to make predictions, especially about the future.” Niels Bohr, Nobel Prize Winning Physicist

Now more than ever, at a time when the horizon of predictability is shorter than it has ever been, organisations and governments must peer into the future and see what’s coming. As we have learned from the disciplines of Superforecasting: The Art and Science of Prediction by Phillip Tetlock and Dan Gardner, as well as the lessons from The Good Judgement Project, this is not impossible – not even now, at a time of high uncertainty, complexity, and so-called digital disruption.

In my line of work, consulting to organisations on people and change management issues, I am seeing this increasingly with questions such as “what will our workforce look like in the middle of the next decade?” And **“what are the key skills needed by our organisation to survive and thrive in the future?”**

This is why we have developed Workforce Shaping, a modern discipline (drawing on some of the Superforecasting lessons) in which we teach our clients to seek to identify possible future-scenarios, to use multiple mind-sets (dragonfly eyed), and to be evidence based using the underlying “run rates” of the system they are seeking to forecast.

Consistently, one of the big things we have learned from Workforce Shaping with clients is that the skills agenda is critical to navigating digital disruption and the impact of AI. But, contrary to what some believe, it’s not all about a headlong rush to recruit or train as many data scientists as possible. Yes, for many organisations, data science is a growing need, but **in addition the skills required for working with AI will be just as important as the skills for working on AI.** The future is about humans and machines working together but in workplaces that are redesigned. Hence capabilities such as design thinking, innovation management, caring, conversing, teaching, and systems thinking will be just as important as coding and creating neural networks. It would be wrong to think that we should swing the pendulum towards everything digital. Instead we need to resolve the dilemma between digital versus analogue.

For government, the skills required for living with AI also feature heavily - such as in relation to developing ethical frameworks, good governance, evidence-based policy



ROBERT BOLTON
PARTNER, KPMG

and, yes, building systems of lifelong learning. Just as well as there will only be a finite supply of people who are capable of undertaking data science careers. Of course, we need to maximise that supply but the 'bell curve' will apply to them just as much as to ballerinas.

The trick is to create organisations and societies that grasp the reinvention of workplaces to make the most of what humans can do, working with AI. This is a challenge of leadership, design, imagination and creation just as much as one of coding.

The challenge is that the need to address the skills agenda is right now. Ahead of the changes that will unfold in the workplace over a number of decades. Professor James Bessen wrote in an article for the International Monetary Fund that politicians could anticipate this by developing policies that focus on developing knowledge and competences for new jobs. He also mentioned that the past offers valuable lessons in this regard: "In the past, training institutions and labour markets sometimes took a long time to adapt to major technologies. For example, during the industrial revolution, factory wages were stagnant for decades until technical skills and training were standardised; when that happened, factory wages rose sharply." The speed at which those task level impacts of AI will occur in our economy mean that there is a lot of urgency about enabling people with the skills of the future. But this requires a system wide redesign of skill acquisition, exploiting those self-same AI technologies to enable learning, which will also impact so much on the rest of the world of work.

The long and the short of it is that we will need a capacity to continually reinvent ourselves over the decades as our workplaces change. We will, in short, need the capacity to learn to learn throughout our lives. Borrowing from The Lord of the Rings, this will be 'the one skill to rule them all.' It will be for policy makers to work out how to enable that and to transform the systems of learning delivery and our educational establishments. This report explores some of the implications of AI and the Future of Skills and we need to act now. As we started on the topic of prediction here's one: The new world of work will rely less on chasing skills at moments in time, like data science, with ever amended curricula; it will rely more on enabling our citizens to play to their strengths, passions and interests. Surely that's the logic behind a more engaging and human workplace and society that is within our grasp, as long as we have the wit to invent it?

Finally a big thank you to Niki Iliadis at the Big Innovation Centre for her excellent work in researching and writing this report on behalf of the APPG AI. **Please explore what we have to say and enter the debate, if you have not already done so. That's our job, role, task as leaders, politicians, citizens, employees and policy makers. It's the 'higher purpose conversation' that requires all our voices, as innovators and, not least, as humans.**

SNAPSHOT



THE ONLY SKILL THAT WILL BE IMPORTANT IN THE 21ST CENTURY IS THE SKILL OF LEARNING NEW SKILLS.

Artificial Intelligence, or more commonly known as AI, is one of the most powerful technologies in the history of mankind. Its implications have already proved far-reaching, impacting all of our economies and societies to a great extent. Moving forward, given the scale and speed of AI's development and deployment, these implications will continue to amplify, spread, and evolve.

Policymakers, in the public and private spheres alike, are under alert. No one knows what the future AI-filled society will look like in ten, twenty, or fifty years, but we do know the transformations will be mind-blowing. The call for us now is to shape policy which will help steer

us towards a future we want to live in – one in which the opportunities of AI technologies are realised and distributed across society and business, and the risks and drawbacks are mitigated.

To untap the potential of AI and to also be prepared to deal with the challenges, individuals across society must possess the ‘right’ skills.

Skills are vital ingredients for an individual’s ability to survive, to thrive, and to shape his or her environment. Being equipped with the ‘right’ skills can empower

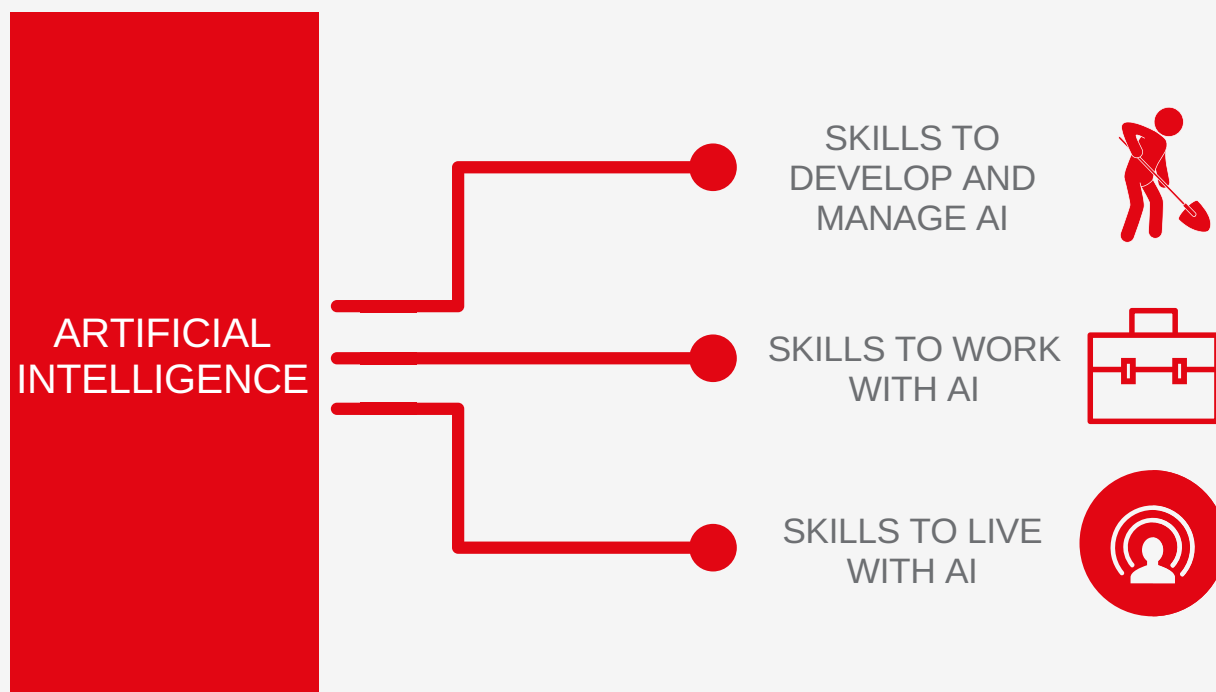
an individual to succeed in all aspects of life, including but not limited to that of work.

**WE ARE NOT ONLY
CONSIDERING THE SKILLSETS
NEEDED TO BE AN EFFECTIVE
EMPLOYEE IN THE 21ST-
CENTURY WORKPLACE**

**BUT ALSO THOSE NEEDED TO BE
AN EFFECTIVE CITIZEN IN THE
21ST-CENTURY SOCIETY.**

We explore AI’s impact on skills in this realm, looking at it through two dimensions.

Figure 1: Three Types of Skills Needed in an AI-Society



I. AI AND SKILLS (DIMENSION 1)

The first dimension looks at AI's impact in what skills individuals should seek to build and policymakers should aim to incentivise.

We deep-dive into the categories of hard skills and soft skills, recognising that an ideal skillset should have a combination of both; and, ultimately, we suggest that policymakers stop thinking of them in silos.

II. SKILLS VIA AI (DIMENSION 2)

The second dimension looks at AI's impact on how these skills are developed, exploring how AI technologies can potentially serve as a tool to build and encourage skills fit for the 21st century.

We further unpack this dimension in two different contexts: (1) the traditional learning environment of the classroom and (2) the non-traditional - yet growing in importance - lifelong learning sphere.

We conclude that:

**IN A WORLD THAT IS UNCERTAIN
AND CONSTANTLY
TRANSFORMING, THE MOST
IMPORTANT SKILL TO HAVE IS
THAT OF LEARNING TO LEARN.**

Figure 2: AI and Skills Dimensions

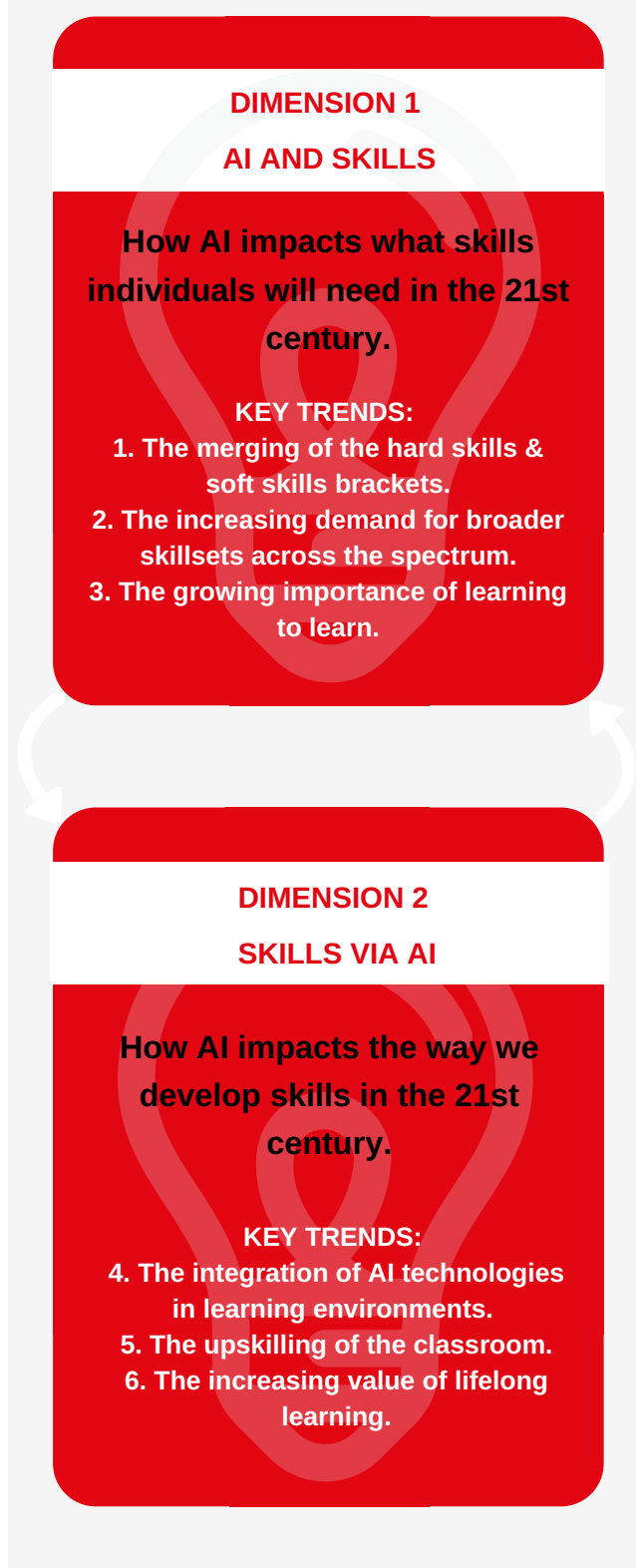


Figure 3: Key Recommendations

RECOMMENDATIONS FOR POLICYMAKERS



Promote skills across the board - from both the hard skills bracket (STEM) and the soft skills bracket (creativity and critical-thinking). **Reward broader arrays of learning.**



Alongside in-demand skills needed to build AI, **develop simultaneously complementary skills needed to work with AI and to live with AI.**



Embed the ethical implications of AI technologies within STEM curriculum.



Restructure formal education and life-long learning curriculum to embed the skill of **learning to learn**. Emphasise this skill in initiatives such as the National Retraining Scheme.



Integrate AI technologies within schools. Ensure all schools, colleges, and universities have access to high speed infrastructure and AI connectivity. **Ensure teachers receive essential training.**



Invest in high-quality careers guidance across the UK. Launch competition for how AI can be applied to **identify, assess, and scale** individuals' abilities and potential.



Fund market research to understand future sectoral and industrial skill surpluses and shortages. Match organisational training and educational initiatives accordingly.



Incentivise and reward organisations that promote lifelong learning opportunities. Create 'best practice' toolkit for organisations, setting clear goals for training schemes, inclusivity, and diversity.

SETTING THE SCENE

INTRODUCING AI AND ITS KEY IMPLICATIONS

WHAT IS AI?

Artificial Intelligence (AI) is receiving growing attention as its economic, social, and ethical impacts manifest across societies.

There is no widely accepted definition; however, for the purpose of this report, we have adopted that used by the UK House of Lords Select Committee on AI. It defines AI as a set of technologies with the ability to perform tasks otherwise requiring human intelligence, and usually have the capacity to learn or

adapt to new experiences or stimuli.

Furthermore, following the work of the All Party Parliamentary Group on AI, we look at it as an "umbrella term" made up of several smaller subfields of science and computational technologies. These include: machine learning, deep learning, robotics, natural language understanding, virtual recognition systems, and autonomous systems (Figure 4).

Figure 4: AI Subfields (based on APPG AI Theme Report 1: 'What is AI?')



Machine Learning



Deep Learning



Natural Language Understanding

ARTIFICIAL INTELLIGENCE

An umbrella term for several smaller subfields of science and computational technologies.



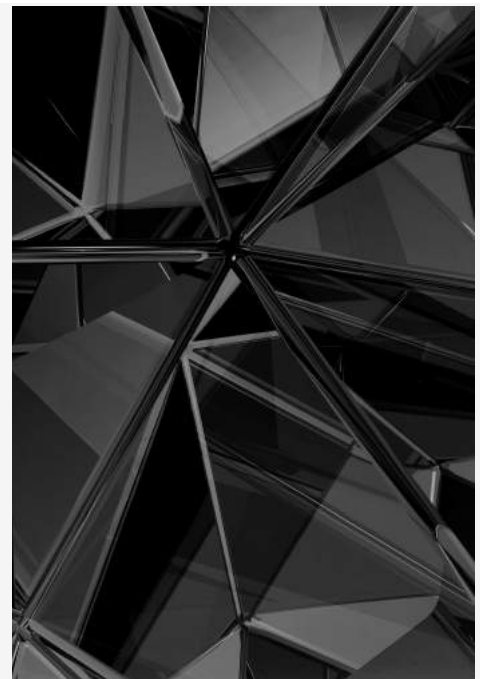
Robotics



Virtual Recognition Systems



Autonomous Systems



WHY NOW?

AI, in this broad sense, can be found all around us nowadays - in almost every type of industry and sector, affecting all of our daily lives in one form or another.

It is far from new though. It has existed for decades, arguably since Alan Turing's publication of *Computing Machinery and Intelligence* and John McCarthy's coining of the term in the 1950s.

Substantial increases in its development and deployment have now given it significant spotlight in both the private and public realms. The availability of big data and computer processing power have made much of the technological progress possible, while the growing number of use cases which illustrate AI's potential have helped escalate its implementation across societies.

WHO WILL AI IMPACT?

AI has been recognised as the most transformative force in the 21st century. Its scale, speed, and complexity are unprecedented, disrupting every industry and sector across the globe.



Ultimately, AI will impact all of us, offering new social and economic opportunities but also significant challenges.

The government, business and the wider public must now address these transformations.

The UK has taken on this responsibility and is in the frontline of designing a strategy which will shape how AI is to be developed and deployed worldwide. The government has recently announced several initiatives, including identifying AI as one of the four Grand Challenges for the UK, committing to a £1 billion AI Sector Deal, and the establishment of the House of Lords Select Committee on AI, a new Government Office for AI, a new industry-led AI Council and a new Centre for Data Ethics and Innovation.

In this same context, the All Party Parliamentary Group on Artificial Intelligence (APPG AI) was also created in January 2017 with the purpose “to explore the impact and implications of Artificial Intelligence, including Machine Learning.”

Chaired by Stephen Metcalfe MP and Lord Tim Clement-Jones, with Big Innovation Centre appointed as the Secretariat, APPG AI aims to bring together key stakeholders to unpack the term AI, to gather evidence to better understand it, to assess its impact, and, ultimately, to empower decision-makers to make policies in the AI sphere. Following the findings of 2017, APPG AI has focused its 2018 agenda on exploring the economic, social, and ethical implications of six key policy areas: AI and Data, AI and Skills (which this report is based on), AI and Accountability, AI and Innovation & Entrepreneurship, AI and Infrastructure, and AI and Trade.

WHAT ARE SOME KEY IMPLICATIONS?

The evidence gathered by APPG AI thus far has highlighted the impact and implications AI is already having in our economies and societies, and will continue to have moving forward.

On the economic domain, AI is likely to boost productivity levels, make products and services more personalised, and bridge existing market gaps. The UK AI Review written by Professor Dame Wendy Hall and Jerome Pesenti, for example, has estimated AI could add an additional £630 billion to the UK economy by 2035, increasing the annual growth rate of GVA from 2.5% to 3.8%.

On the socio-ethical domain, AI's potential for individuals' wellbeing, health, security and education is profound. Millions of lives can be saved with the introduction of AI into healthcare.

“HARNESSING THE POWER OF TECHNOLOGY IS NOT JUST IN ALL OUR INTERESTS – BUT FUNDAMENTAL TO THE ADVANCE OF HUMANITY. BUT THIS TECHNOLOGICAL PROGRESS ALSO RAISES NEW AND PROFOUND CHALLENGES WHICH WE NEED TO ADDRESS.”

– Theresa May

[World Economic Forum Annual Meeting, 25 Jan 2018]



Children worldwide can benefit from more personalised and accessible education.

But, simultaneously, AI is posing complex and multi-faceted questions for our societies and ethical values. Can the notion of privacy exist in a data-driven economy? What will human relationships look like in the the future? How do AI systems reflect biases in society? Do AI technologies have the capacity to manipulate individuals? Who is accountable for an automated decision gone bad?

And, lastly, for the purpose of this report:

1. WHAT SKILLS WILL INDIVIDUALS NEED TO WORK - AND LIVE - IN AN AI-FILLED SOCIETY?



2. HOW WILL WE BUILD SKILLS MOVING FORWARD, IN BOTH TRADITIONAL AND NON-TRADITIONAL CONTEXTS?

AI AND SKILLS

LOOKING AT HOW AI IS IMPACTING THE SKILLS INDIVIDUALS WILL NEED IN THE 21ST CENTURY

HOW WILL AI TRANSFORM LABOUR?

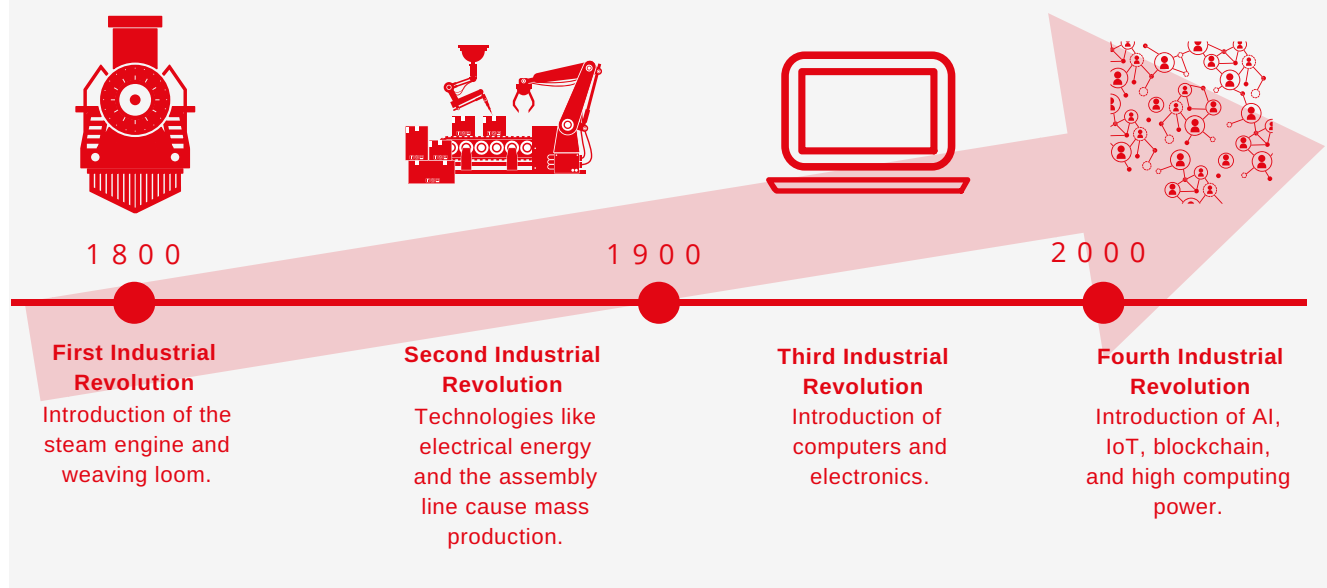
One of the critical areas AI is expected to have substantial impact in is the labour market.

With the turn of the millennium, society is starting to question what the introduction of new technologies - like AI - will mean for their jobs.

This debate has reoccurred in the past. During the First Industrial Revolution, society was concerned how steam engines and spinning jennies would impact their employment rates, wages, working hours, and the, overall, nature of work.

Historically, however, the long-term benefits of technological advance have ended up outweighing the short-term dangers. This can be explained through the simple reality that labour is not a fixed sum. Labour replaced by machines

Figure 5: The Four Technological Revolutions



brings down prices of products and, hence, increases real incomes. Over time, demand for new goods and industries to supply them increases and, consequently, new jobs are created. Therefore, in the past, although new technologies have disrupted the labour market, they have ultimately created more jobs than diminished.

Will AI benefits in the labour market continue to outweigh the risks, as seen throughout history? Or, is this transformation, caused by AI, different from the preceding ones?

The technology of today is different because it has the capacity of doing much more than the technology of the past.

WHILE IN THE PAST, INVENTIONS SUCH AS THE AUTOMOBILE OR THE TELEPHONE HAD THE POWER TO REPLACE THE HUMAN HAND, AI TECHNOLOGIES OF TODAY HAVE THE POTENTIAL TO REPLACE THE HUMAN BRAIN.

Cognitive automation, more than just physical automation, is now possible.

Humans have always enjoyed a monopoly over the former and, thus, there is now a growing concern that as AI advances even white-collar professions will be at risk.

A series of academic and corporate reports have been recently launched, attempting to disclose exactly what the impact of technology on jobs will be.

Figure 6: Sample of Recent Reports on Job Automation



Although there is disagreement amongst these reports on what the actual impact of AI will be on the labour market, all can agree that the disruption will be significant.

Simply put, many of the jobs existing today will not exist in ten years; and, likewise, many jobs of the future don't exist today. In fact, a report from the World Economic Forum estimated that 65% of children entering primary school today will work in completely new job types that don't exist yet.

Such findings have societies across the world wondering: what will the future labour market look like? How should we prepare? The pessimists are concerned this will lead to mass unemployment, inequality, and social turmoil, while the optimists view this as a window of opportunity – in which human beings will be freed from the burden of day-to-day drudgery and, consequently, can dedicate their time to things of bigger purpose.

Whether a pessimist or an optimist, one thing is for sure: jobs in the labour market of the future will look very different from today and the transformation will be rocky.

The UK must build an agile labour market fit for these transformations. Government programmes such as the National Retraining Scheme are vital to ensure citizens are equipped to succeed in the new economy forming.



KEVIN GREEN

FORMER CEO, RECRUITMENT
& EMPLOYMENT
CONFEDERATION (REC)

The jobs market in the UK is performing well, we have close to full employment; with (in February) a record 32 million people in work (over 3 million more than in 2010), the employment rate is at a record high of 75 percent, and unemployment is at the lowest since 1975. There are concerns over the 'quality' of work, but in comparison to many of our international competitors, the UK is doing very well.

Artificial Intelligence, however, will impact on millions of jobs in the UK. As we continue to automate cognitive - as well as manual - tasks and as machine learning is close to overtaking our ability to ingest, process and pass on data, significant numbers of jobs will be lost. PwC have estimated that up to 30% of UK jobs could potentially be at high risk of automation by the early 2030s, and Martin Ford in his book *The Robots are Coming* claims that 38% of jobs will be lost.

Previous changes have always destroyed jobs; with the shift away from agriculture 100 years ago, and with

manufacturing being replaced with service jobs over the last 60 years. The AI revolution is likely to bring about much quicker change.

OECD data shows that over the last 20 years it has been jobs in the middle of the jobs market that have been destroyed; while lower and higher skilled jobs have seen growth. Automation is likely to accelerate this polarisation, which could result in greater inequality, and fewer progression opportunities. Policymakers must work closely with the recruitment sector and the wider business community to pre-empt these changes and help individuals navigate the changing employment landscape.

Increasing life expectancy is changing the way people think about work. To facilitate people retraining and adapting throughout their working life, we need an all-age work advice service, which harnesses the contribution of employers and recruitment experts. Helping older workers make transitions and reintegrate into the jobs market is a key element of the REC's work on inclusion.

At the other end of the spectrum, our education system must prepare future generations for the changing world of work with continued emphasis on creativity, teamwork, collaboration and selfdriven learning. To facilitate future progression opportunities for all, the government should ensure that the Apprenticeship Levy should be broadened into a training levy that can meet the training needs of workers in non-permanent roles.

WHAT IS THE IMPACT OF AI ON SKILLS?

One of the most forceful AI narratives that has formed – and closely related to the transforming labour market – is that around skills. Skills are closely related to economic growth and productivity, as well as individual wellbeing and self-fulfillment.

AS AI FUNDAMENTALLY TRANSFORMS BOTH THE QUALITY AND QUANTITY OF JOBS AS WE NOW KNOW THEM, THE SUPPLY AND DEMAND OF SKILLS IS SIGNIFICANTLY SHIFTING.

Organisations and businesses realising the economic opportunities of developing AI and implementing it in their business models are seeking individuals who can build and manage AI technologies. Titles like machine learning engineer, computer vision engineer, and data scientist are among the most in-demand jobs at the moment. AI skills broken down into machine learning, data science, Python, R, big data, Hadoop, Java, data mining, Spark, and SAS are the most popular amongst job candidates.

Currently, there is a worldwide shortage of this type of talent.

Gartner recently named the skills gap the biggest factor in why almost 60% of organisations have yet to take advantage of the benefits of AI. Similarly, Ernst and Young's poll of business leaders across the globe found that 80% of respondents are concerned with the lack of talent available to fill AI-related positions.

According to Indeed, an online platform to search for jobs, the number of available AI roles in Britain has increased by 485% since 2014 but there are over two times as many AI jobs available than there are suitable applicants, with a ratio of 2.3 roles available per candidate searching.

The reality behind these numbers has caused big tech firms - like Google, Amazon, Microsoft, IBM and Facebook - to compete with one another to find and hire from the limited pool of candidates available. The brightest minds are often lured with extremely high salaries and benefits. Smaller companies, bounded by limited resources, have difficulty competing with these packages and are frequently left with second-choice candidates who lack the advanced skills needed to develop these complex AI systems.

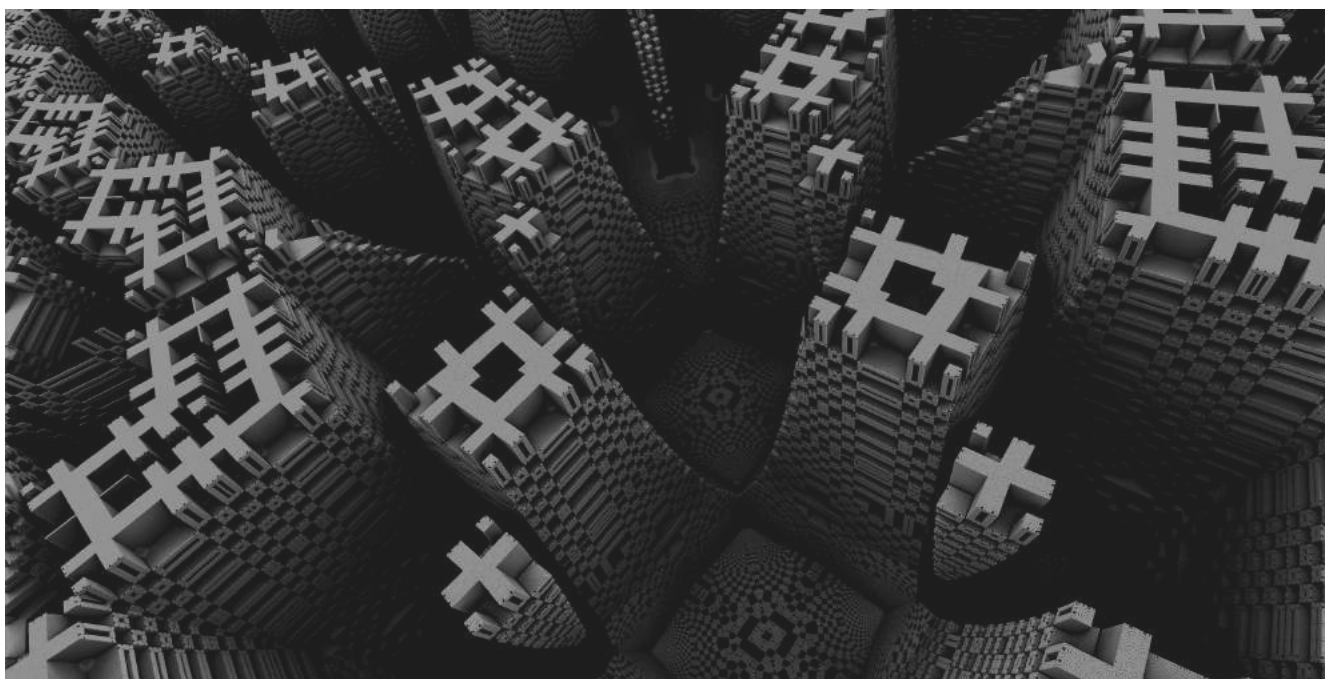
UK policymakers, conscious of the skills gap, are already trying to address this inefficiency in the labour market, implementing strategies to attract talent from abroad and to develop talent within. In the Industrial Strategy, for instance, the UK announced they will be taking pivotal steps to assure they have access to individuals with AI skills. They committed to 2,000 visas per year to attract the best and brightest talent from science, digital technology (including specialists in AI), engineering, arts and creative sectors. Furthermore, they have launched a new Start-Up Visa to help maintain the UK's position as a world-leading destination for innovation and entrepreneurs.

Policies such as these are starting

to be implemented, but there is still a long way to go before the supply and demand in the labour market aligns.

In the programme of the APPG AI, the issues around AI and skills have repeatedly been highlighted as the areas of high priority for government, business, and wider society to deal with. On 26 February 2018, the group met to discuss this very issue. Five experts across industries and sectors were invited to provide oral evidence.

They included Jonnie Penn (AI Researcher, Cambridge University and Google Policy Technology Fellow), Robert Bolton (Partner and Head of KPMG's Global HR Center for Excellence), Kevin Green (Chief Executive at The Recruitment and Employment



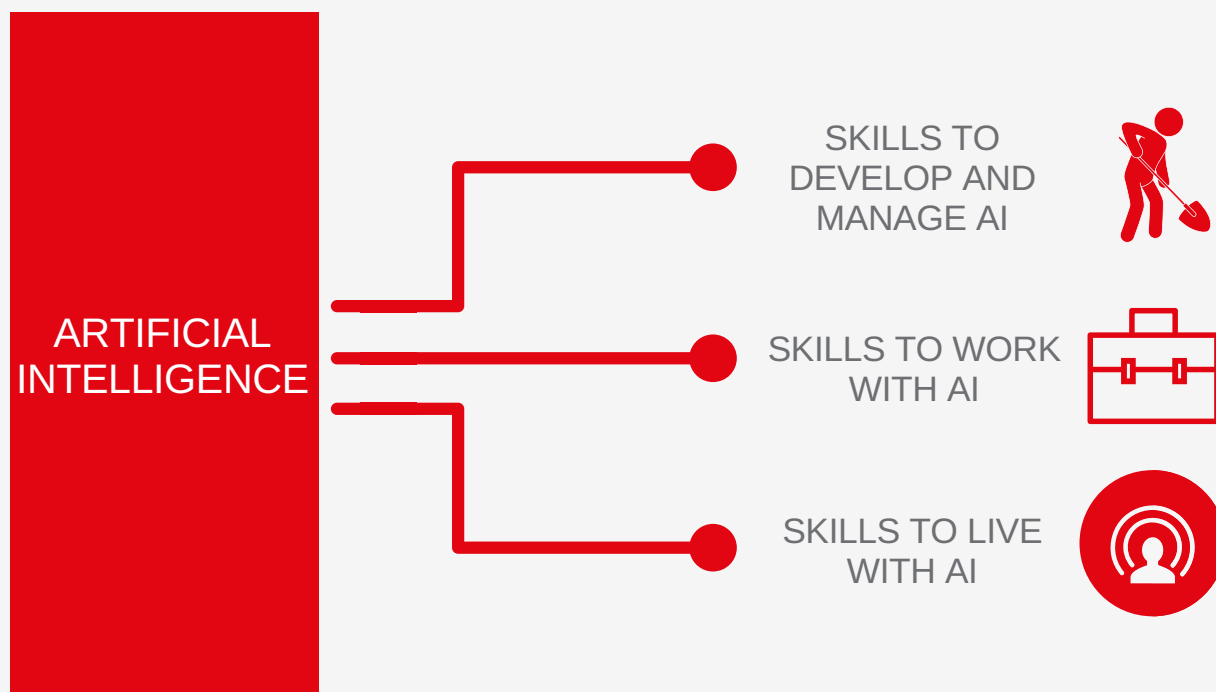
Confederation), Ali Shah (BBC's Head of Emerging Technology and Strategic Direction), and Beverly Clarke (former teacher and author of "Computer Science Teacher"). All five of the experts and the wider audience of over 100 individuals across government, academia, and industry concluded that the growing skills gap in a rapidly emerging AI-filled society should be of upmost priority for policymakers to address.

Ultimately though, our evidence showed that AI is not just increasing the demand for people who can build AI, AI is also creating a need for individuals who can work with AI. It is now

accepted that AI will impact jobs across all industries and sectors – massively transforming routine and non-routine tasks across the board. This means that individuals will need to be equipped with a new set of hard and soft skills, empowering them to work alongside AI and its transformations. Individuals will need to have the skills needed to make sense of AI, commercialise it, and manage it. Individuals will need the skills needed to work with AI, to help them increase efficiency and productivity as they use it in both routine and non-routine tasks.

Moreover, however, AI is having

Figure 7: Three Types of Skills Needed in an AI-Society



profound and complicated implications in spheres that transcend that of work. AI is changing entire communities, relationships, social structures and existing notions of what ought and ought not to be.

Hence, when unpacking the question of what skills individuals should be equipped with moving forward, policymakers must look further than just labour implications and what skills individuals will need to succeed as future employees.

WE MUST CONSIDER AI'S IMPLICATIONS IN A MUCH WIDER SCOPE - IN ORDER TO PROMOTE AND BUILD SKILLS IN WHICH INDIVIDUALS WILL NOT ONLY SURVIVE AND THRIVE AS WORKERS BUT ALSO AS CITIZENS.

In other words, as the scale and speed AI is developed and deployed increases, we will see a growing need for not only individuals who can build AI and work with AI but also those that can live with AI.

We will need individuals who are adaptable and have the power to continuously learn in a constantly changing world.



PROFESSOR MARGARET BODEN

AWARD WINNING THOUGHT LEADER IN AI;
RESEARCH PROFESSOR OF COGNITIVE
SCIENCE, UNI. OF SUSSEX

Our society will be increasingly reliant on AI, including machine learning (ML) and robotics. Some citizens will choose to make it, many will have to use it, and all will be forced to live with it. This will require education/training at all levels, and for all ages.

Making AI/ML can be done only by very highly-skilled individuals. These will be professional computer scientists, plus others specially trained to work with them.

Much (not all) ML—especially the types that deal with Big Data—is based in statistics and probability theory, and much (not all) of that uses neural networks. Traditional “symbolic” AI doesn’t use probability or neural networks, but is based instead in logic. So today’s computer science degrees are not a good training for high-level work in ML: that must change.

There will also be a need for intensive MSc degrees for knowledge transfer,

aimed to provide these newly-relevant skills to post-graduates who are not computer scientists, and perhaps not even STEM-educated. The obvious parallel is the Alvey Programme of the 1980s, which provided skills in writing and working with AI expert systems to students from a wide range of backgrounds.

Even high-level skills are grounded in early education. Hence the (very welcome) recent decision to make computer coding mandatory in schools. However, future primary/secondary courses (and youngsters' computer clubs) will need to introduce children also to neural networks, databases, and probability. This is a challenge because we think more naturally in terms of logic and arithmetic than probability theory.

Special diplomas should be available for schoolteachers. At present, only a minority of schoolteachers have any computer qualifications, and these are unsuitable for ML anyway.

Using AI/ML will be a dominant feature of work for many people, in virtually all areas of employment. Both further and higher education should provide courses to prepare people for such experience. Sixth-form colleges should do so, too.

Specialist courses in data-management should be made widely available, too. Preparing data for use in Big Data applications is far from a trivial exercise.

Living with AI/ML will not be open to choice, as this technology will be ubiquitous. At every educational level, from primary school onwards, people will need to be alerted both to its potential and to its limitations.

For example, to what extent are probabilistic ML systems “black boxes”, which even skilled computer scientists can't predict and don't understand? (The designers of AlphaGo, which beat the human Go champion in 2016, don't know why it made the winning moves that it did.) What sorts of bias can be knowingly or unknowingly included in databases? Are any sorts of data impossible to digitise? To what extent can individual-specific information be recovered by inference from anonymised data?

In sum, It won't be necessary for every citizen to be a good coder, much as not every car-driver needs to be a mechanic. But everyone will need a sense of what sorts of things AI systems can do, and—perhaps even more important—what sorts of things they can't (yet?) do. If they have some idea of how the systems work, and therefore of what general sorts of things might go wrong, so much the better. That will protect the populace from being misled by the various types of hype which attend AI/ML.

WHY HARD SKILLS MATTER?

Through this lens, it is easy to appreciate the growing importance of hard skills in the AI-filled society starting to already take form around us. We need hard skills to create AI, to work with AI, and to live with AI.

When we refer to hard skills, we are alluding to those skills that are tangible and easily quantified or measured. Within this bracket belong the skills mentioned above – those that empower individuals with the capability to build and manage AI systems. All of these skills fall under the STEM (science, technology, engineering, and mathematics) category and are often considered the practical skills individuals need to get a job done and our economies need to prosper.

The APPG AI has highlighted the importance of hard skills in our transforming society. Particularly, our oral evidence has highlighted the need to develop explicit AI skills as well as engineering, digital, data science, and computer science skills.

According to LinkedIn, the most in-demand hard skills for 2018 are:

- cloud and distributed computing
- statistical analysis and data mining
- middleware and integration software
- web architecture and development framework
- user interface design
- software revision control systems
- data presentation
- SEO/SEM marketing
- mobile development
- network and information security

As the demand for these types of skills increases, policymakers and other key stakeholders are looking for ways to promote their development throughout different learning contexts.

Formal and informal curriculums are being restructured, putting much more emphasis on the building of hard skills - from primary school all the way to higher education.

Specifically, policymakers are creating additional courses and places to generate new high-skilled individuals across the UK, improving the responsiveness of

the skills training system to changing demand, reducing the gap between industry and academia and addressing the diversity gap by creating opportunities for women and other underrepresented groups.

Several educational campaigns are being launched to push children into these areas and to promote diversity across all UK regions.

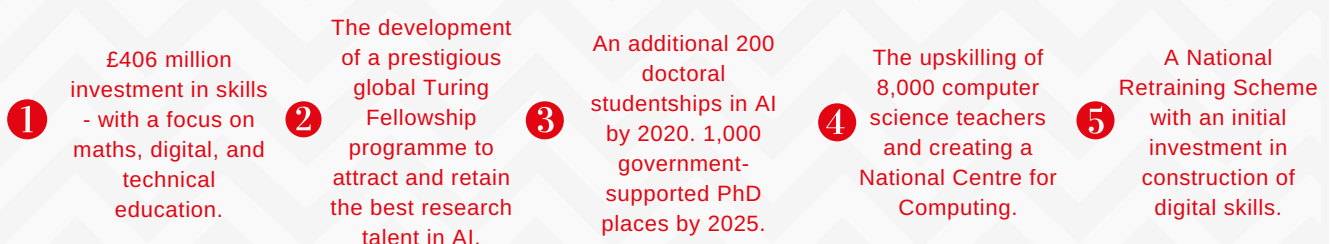
For example, the government has named 2018 as the Year of Engineering. This signals a year-long campaign committed to boosting engineering skills across the UK. On the campaign's website, their goal states "A career in engineering is exciting, rewarding and creative. Yet there is a big shortage of young people that think it could be a job for them. Over the course of 2018, we want to shake-up people's ideas about engineering, inspiring the next generation of innovators, inventors and problem solvers by showing them what engineers actually do."

Campaigns such as the Year of Engineering are vital in hopes to encourage both younger and older generations to invest in the bracket of hard skills.

The UK's national academy for engineering, the Royal Academy of Engineering, are further accelerating this mission. For over forty years, the Royal Academy of Engineering has been advancing and promoting excellence in engineering; but, with the introduction of AI and other related technologies, the need for engineering skills is now higher than ever. The Royal Academy of Engineering, aware of the transformations unravelling, are taking a pivotal role in promoting and building these in-demand skills.

As the importance of hard skills grows, it is key to ensure our younger generations develop those skills that will help them succeed and our older generations upskill with those skills that will safeguard their competitiveness and wellbeing.

Figure 8: Recent UK Government Initiatives to Boost AI Skills (as part of AI Sector Deal)





PROFESSOR JONATHAN SEVILLE, FRENG

CHAIR OF EDUCATION AND SKILLS
COMMITTEE, ROYAL ACADEMY OF
ENGINEERING

Engineering ways of thinking encompass exactly the attributes that are necessary to create a self-adapting workforce comprised of individuals that thrive in a fast-changing world of work. Key engineering ‘habits of mind’ comprise problem finding, creative problem-solving, systems thinking, adapting, improving and visualising (Figure 9). And yet engineering is virtually invisible in the education system until the latter years of secondary education. Nurturing engineering habits of mind in the education system would lay the foundations for developing more and better engineers that can think for themselves, solve problems with others and persist in the face of difficulty. It requires teaching and learning methods that value practical and applied approaches – that young children naturally demonstrate through play - to balance their more abstract and theoretical studies.. Increasing participation in well-designed project-based and problem-based learning would provide an excellent preparation for the kinds of wider life skills that we all need in order to be able to thrive, not just engineers.

The context in which such skills are needed is also changing: distinctions between IT, technology and science are fast collapsing; the solution to a problem may lie in any combination of these. Collaborative and cross disciplinary ways of working are gaining ground, and engineering, with its focus on the interface between technical systems and the operational human experience, is critical to understanding and shaping this fully . The technical skills pipeline remains a fundamental challenge both within and across sectors, while other important skills include design, strategic planning, leadership and change management. Professional education will increasingly need to prioritise the development of those who can lead or be part of cross-disciplinary teams.

Figure 9: Engineering habits of mind (Centre for Real-World Learning)



WHY SOFT SKILLS MATTER?

However, as we strive to equip individuals with in-demand hard skills, we should not ignore the importance of soft skills. We think of soft skills as those less tangible and harder to quantify. Many also refer to them as interpersonal or personal skills.

According to a LinkedIn survey of 2,000 business leaders, soft skills in future candidates are actually found much more important than hard skills. The survey shows that employers looked for individuals who demonstrated the following specific soft skills:

- leadership
- communication
- collaboration
- time management

Creativity, problem-solving, and critical thinking skills are also part of this bracket. And, both written and oral evidence at the APPG AI have stressed the importance of this 'soft skills' bracket in the context of an emerging AI-filled society.

WE NEED INDIVIDUALS WITH CREATIVITY AND CRITICAL-THINKING SKILLS TO TAP THE TRUE POTENTIAL OF AI.

Figure 10: Top Hard Skills and Soft Skills (based on APPG AI evidence)

Hard Skills	Soft Skills
Computer Science Digital Engineering Data Science Design Thinking	Creativity Problem-Solving Critical Thinking Adaptability Leadership

These soft skills are arguably the group of skills that humans will have a competitive advantage in over machines. Therefore, individuals who are equipped with these skills, will likely be in lower risk of their job being automated in the long-run. As AI emerges and reshapes many of the tasks associated with our work, the soft skills are what individuals will need to adjust and retrain.

Soft skills are also becoming increasingly important as we seek people who will be able to work alongside AI and to ensure its deployment in society is widely beneficial. We need soft skills to lead AI development and deployment, to communicate the problems and opportunities across stakeholders, to work with teams to create solutions, and to manage time in a manner that proves efficient both in the short-term and long-term.

**JONNIE PENN**AI RESEARCHER,
UNIVERSITY OF CAMBRIDGE

A report by the Aspen Task Force on Learning and the Internet published in 2014 identified three essential literacies for the digital age: digital literacy, media literacy, and social-emotional literacy. This list of competencies roughly aligned with four "types of intelligence" put forward in 2016 by Klaus Schaub, founder of the World Economic Forum, as key to success in what Schaub characterised as the coming Fourth Industrial Revolution. This revolution is said to be marked by the convergence of various emerging technologies including artificial intelligence (AI), advanced robotics, big data, and the Internet of Things (IoT). Within this economic trend, the potential exists for the physical, digital, and biological worlds to become increasingly "fused," causing change to the ways in which we live, work, and relate.

The UK government can prepare for the risks and opportunities implied by this or an analogous future in two steps. First, ensure that world-class STEM training is made affordable and accessible to a diverse set of candidates in the UK. This could include introductory curricula on probability, databases, and neural networks in secondary school, and/or funded conversion masters on AI that facilitate transitions from the social sciences, natural sciences, and humanities. Second, and more broadly, policymakers can take steps to ensure that four varieties of intelligence are nurtured in both formal and informal educational settings to compensate for the social and political upheaval that would accompany the sort of change Schaub forecasted. Those varieties are: contextual intelligence (i.e. data literacy), emotional intelligence (i.e. social and emotional literacy), physical intelligence (i.e. health and wellness), and creative intelligence (i.e. self-actualisation). This list consolidates the proposals of the Aspen Task Force, Schaub, and other similar frameworks (see: The Pineapple Report, forthcoming).

The value of the first three varieties of intelligence is increasingly self-evident. In the United Kingdom, 17% of the population lack basic digital skills (White, 2017). Only 9% have heard of 'machine learning' (Ipsos Moritz, 2017). Alongside this, the percentage of jobs at risk of automation for young workers aged 16-24 range in estimate from 20-40% (PwC Young Workers Index, 2017). A 2017 OECD report suggested that only 11% of adults worldwide are currently above the skill level in literacy and numeracy that subdomains of AI, like natural language processing, are close to reproducing. To address this gap in both skills and awareness, and to prepare the public for citizenship in a digital era, governments and organizations should invest in mechanisms that allow everyday people to participate in civic life in ways that also teach digital literacy. Candidate solutions include: citizen juries, digital field hearings, local e-government programming projects, and personal government account managers (see: Technology for the Many, 2017). Such mechanisms, if scaled, could allow the general populace to learn about, criticize, resist, appreciate, and/or ultimately improve the digital and AI-powered systems they intersect with in everyday life. In regard to emotional and physical intelligence; old and new strategies exist here as well (Pineapple Report; forthcoming). For example, intergenerational mentors and dialogues could be used to foster emotional intelligence in youth. This is not just proactive work; reactive interventions are also needed. For example, regulatory oversight may soon be required to prohibit so called "dark patterns" or other predatory design mechanisms that, in certain cases, prey on and serve to normalise short attention spans or social isolation (Time Well Spent, 2018). Care is also needed to mitigate the escalating toll of digital technologies on public health and the environment (see, for example, the anti-obsolence movement).

Lastly, on the topic of creative intelligence, it is important to note that there is a risk in overfitting the UK's education system to the perceived needs of any hyped emerging technology, not just AI. Diversity of experience and expertise, be it artisanal, vocational, craft, or otherwise, remains a key driver of vibrant civic culture. Diversity of experience also contributes to technological innovation. In the 1950-60s, the UK computer industry suffered greatly as a result of computer programming being purposefully re-framed as a 'masculine' activity, which pushed out a generation of expert female programmers (Hicks, 2017). An equivalent error could be made today. To ensure an inclusive, prosperous future, different varieties of intelligence should be embraced and nurtured in a manner analogous to, for instance, the protection of biodiversity in a woodlands. Since research shows "a key determinant of motivation is autonomy," then this protection of diversity, if legitimate, requires in turn that the realities of modern data-governance be laid bare (Barton, 2018). In short, the digital economy must remain competitive and open to new entrants in order for diversity to thrive. To facilitate this outcome, policymakers should trial models of data-governance that prioritize democratic notions of "access" and "control" over the 20th-century trappings of "ownership."

IS HARD VS. SOFT A FALSE DICHOTOMY?

However, framing the skills conversation as hard skills versus soft skills is proving to be a false dichotomy.

In the 21st century world, individuals could and should have a combination of both.

One category should not be sacrificed in order to develop the other. From primary school to higher education, and ultimately spanning across one's lifetime, individuals should be equipped with both hard and soft skills in order to survive and thrive.

It is fallacious to consider these two categories as conflicting. In fact, hard skills and soft skills are

complementary and should not be thought of as mutually exclusive. Even for tasks that require deep technical skills, such as building an AI system, if the individual cannot problem-solve and think critically about the product or service, the project is unlikely to be successful.

Policymakers ought to encourage and incentivise a broad set of skills from both hard and soft categories but, even more so, start appreciating and rewarding skills across the spectrum.

FUTURE EMPLOYEES AND FUTURE CITIZENS SHOULD POSSESS SKILLS ACROSS THE SPECTRUM IN ORDER TO SURVIVE AND THRIVE IN AN AI-FILLED SOCIETY.

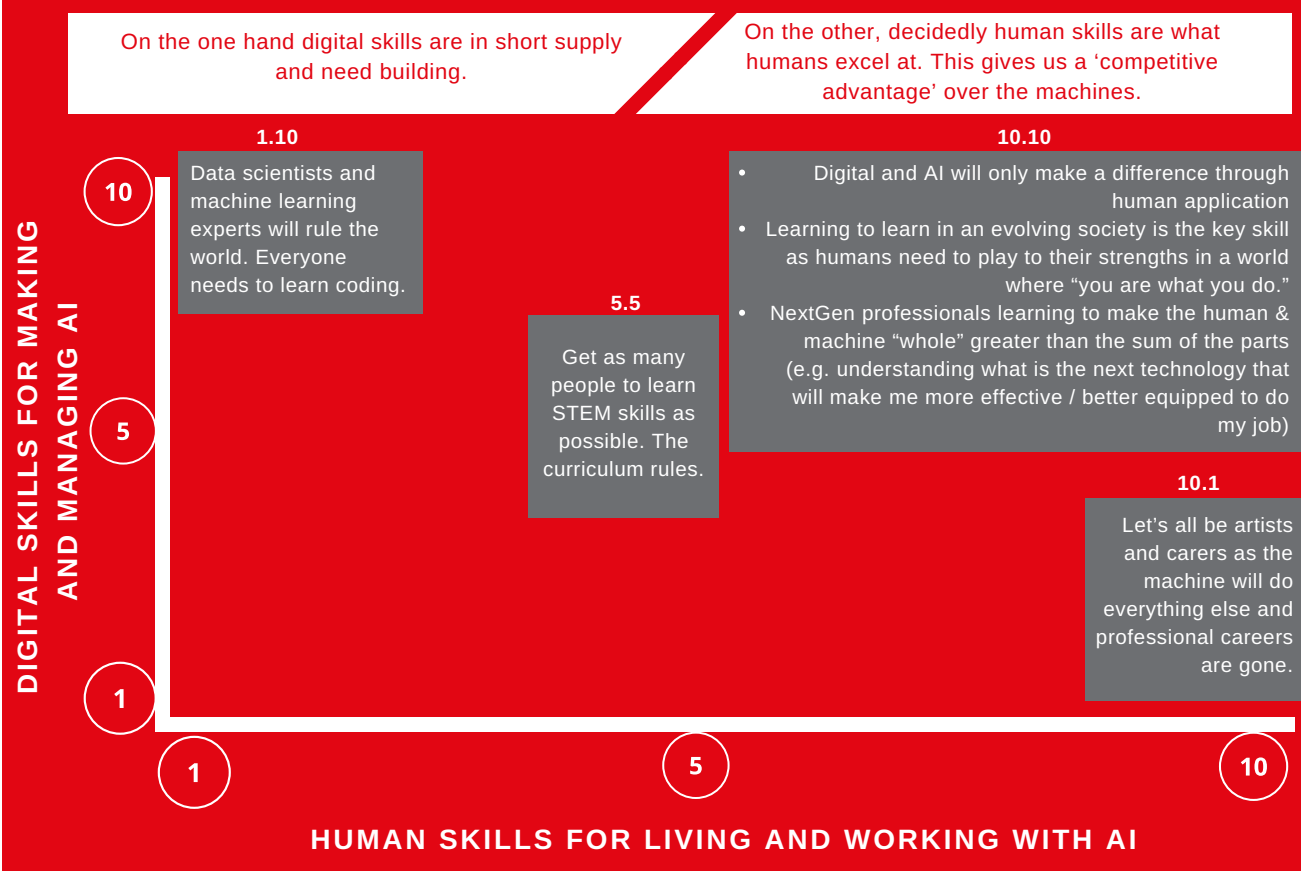
ROBERT BOLTON
PARTNER, KPMG



Dilemma Reconciliation is a practical and structured approach to deal with, and bridge competing demands and interests that exist and manifest in an organisation's strategy or in wider society. It is an antidote to bi-polar thinking such as "the future is all digital" or "robots will replace all our jobs."

- The outcome of the Dilemma Reconciliation Process can be used to define, build or change strategy and culture. Undertaking dilemma reconciliation always leads to new insights and innovation as the prevailing mind-set that is required is one of creation through reframing seemingly intractable **either / or** choices.
- Dilemma Reconciliation was developed by two leading academics and management thinkers: Fons Trompenaars and Charles Hampden-Turner.
- Dilemma Reconciliation in its most complete form is a six-step structured process to identify, understand and address an organisation's or society's key dilemmas. It involves charting the dilemmas, as shown in the diagram, and providing a characterisation of the extreme position of each side of the dilemma (10.1 and 1.10). It also requires the positives and negatives of each pole being described. The compromise (at 5.5) is further explored and through a process of framing and exploring one side through the other and vice versa there becomes a new reconciled position at 10.10. Figure 11 below provides a summary.
- It is used when a problem that has opposing perspectives attached to it, meaning a dilemma, is at the heart of the issue. It is particularly useful when needing to move beyond bi-polar, linear thinking and thereby creating respect for diverse viewpoints.

Figure 11: Future of Skills: Why learning to learn resolves the dilemma between digital and analogue skills (KPMG)



In this report there is only space to summarise our thinking on the dilemma at the heart of identifying the future skills needed in the UK, as a result of AI. But suffice it to say we think there is a dilemma at work and it's summarised in Figure 11 above. The dilemma is often wrapped-up in language from commentators arguing, on the one hand, for a strong drive to invest in 'hard' or digital skills. These people advocate a drive for as many adults and children to follow a STEM based curriculum and world of work. The underlying rationale being that the future is digital and AI driven and we need to develop and manage these technologies if individuals and the UK economy as a whole, is to survive, thrive and grow.

The problem with this is that those people suited to a data science based education and career will occupy a normal distribution (bell) curve just as people with any other skill do so as well. We each have different strengths and motivations. We cannot create an entire population of data scientists and neither should we.

On the other side of this dilemma, therefore, are those who argue for a distinctly human future, often on the basis that machines will do the technical stuff. Not many people are needed to design and run the machines, so we need to develop our softer analogue capabilities. We are analogue beings and we excel at artistic, craft, inter-personal and caring skills. This type of thinking is likely to be equally wrong and damaging.

Dilemma reconciliation thinking also teaches us to be wary of the classic compromise. This would mean a bit of digital skill development, as much as we can have, and a bit of analogue skills development too. True reconciliation will come from developing our digital and AI skills **through** developing our analogue futures and vice versa. Dilemma reconciliation avoids **either / or** and **and / both**. Instead it requires innovation to secure the development of one pole of thinking **through** the development of the other pole. This thinking led us to the insight that actually, the future of skills is not about picking a skill or indeed a list of skills. It's not about STEM skills as the pinnacle of achievement any more than it's about nurturing our purely analogue skills. It's fully about learning to learn in a world where our futures will be inextricably linked with managing, working with and living with AI in a more fluid way. One where because of the task level impacts of AI we will need to constantly reinvent our organisations and our capabilities throughout our lives. A world where any curriculum needs a "teach by" date and any skill needs, if not a "use by" date then a "review by" date.

SKILLS VIA AI

EXPLORING HOW AI IS TRANSFORMING
THE WAY WE DEVELOP SKILLS

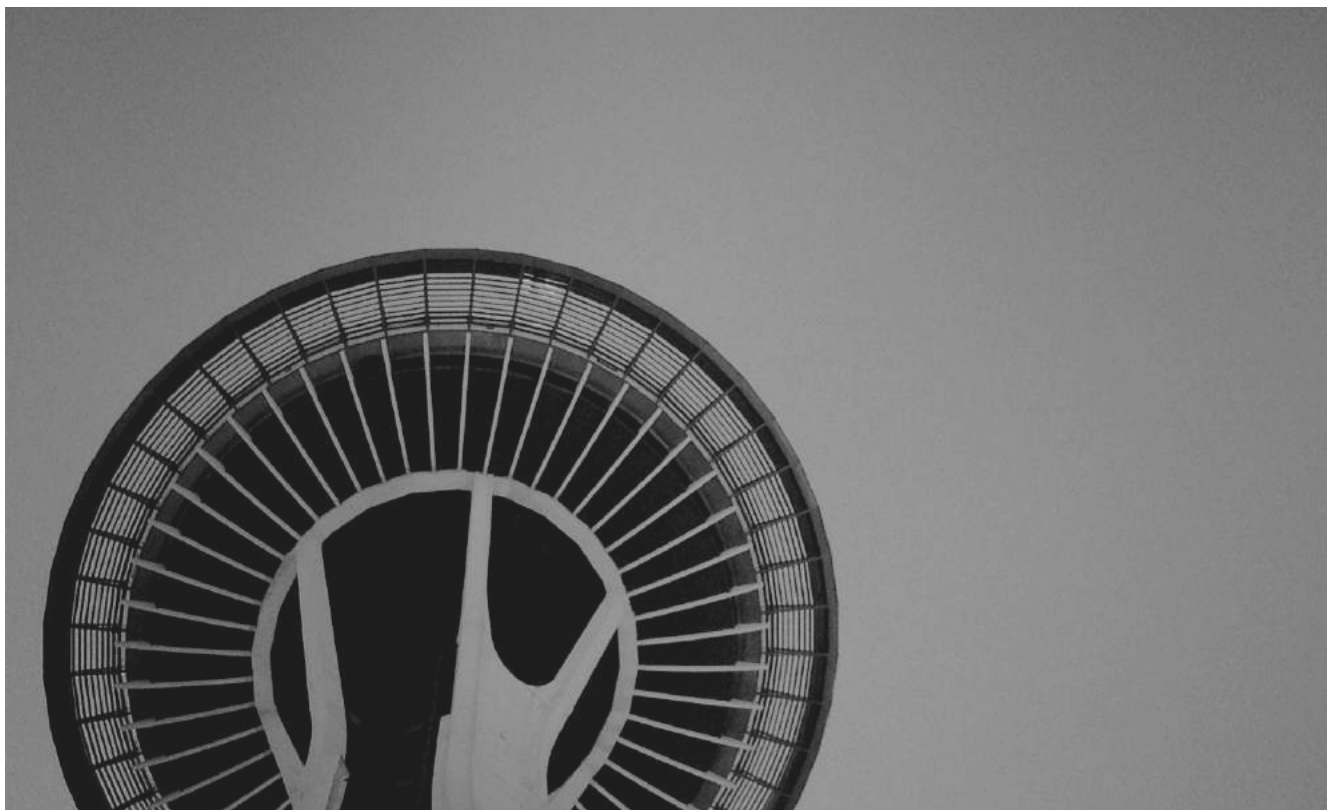
HOW DO WE DEVELOP SKILLS?

The way individuals, across all stages of education, learn and develop skills in the 21st century is significantly transforming. New technologies mean we will learn in ways that do not exist now.

Society can use AI as a tool to develop both

the soft and hard skills individuals will need to survive and thrive. Technologies can help extend our learning and cognitive possibilities.

AI can be used to help identify the skills one is excelling in and ensure the appropriate guidance is provided



to further advance and exploit these skills.

AI can be used to help identify the skills one is lacking and provide him or her with the support needed to develop these skills.

AI advances, in many ways, are helping merge the hard and soft skills categories together. Soft skills have traditionally been more difficult to assess compared to hard skills, but this is changing with the application of some AI systems with the capacity to measure and assess less quantifiable variables. Soft skills have also traditionally not been thought of as those you can teach. Again, AI is changing this.

AI can be applied in different scenarios to help facilitate learning.

**WITH AI, EVERY CHILD
ACROSS THE WORLD CAN
HAVE ACCESS TO QUALITY
LEARNING.**

Learning now has the potential to be active, authentic, and cooperative. Learning can happen anywhere.

A teacher can now use a machine learning algorithm to analyse and find correlations between data points and quantify his/her student's understanding of a specific topic. Children can now be equipped with a personal

digital tutor to help them in courses they need an extra boost in. The applications of AI in education are enormous and so is the potential.

The future of learning is now involving online classrooms, peer to peer interactions, and student-employer direct connections.

However, we are far from realising the full impact of AI on learning - from how we create learning experiences to how we assess skills.

Policymakers must work with industry and academia to recognise these opportunities.

Figure 12: EdTech Examples



Smart Content

Content, information, and knowledge can now be intelligently personalised or tailored to match the needs of each student. Examples include smart digital content platforms to allow learning to take place anywhere and smart study guides with practice tests and interactive flashcards.



Teaching Assistants

Robots or other AI systems can serve as aides for teachers in the classroom, helping answer student questions with speed and accuracy, and analyse classroom engagement. AI teaching assistants can revolutionise educational environments, helping teachers teach and students learn.



Peer to Peer Learning

AI can facilitate peer to peer learning - making it easier for students to ask questions to one another and connect globally. Moderators can be used on these platforms to verify questions and answers and retain high-quality.



Intelligent Tutoring Systems

Students who need extra guidance on a subject can have a one-to-one personalised tutor that offers him/her real-time feedback, a curriculum and opportunities for improvement. AI can track student strengths and their weaknesses.

HOW TO UPSKILL THE CLASSROOM?

These transformations can take shape in two different learning contexts.

The first context is the traditional learning environment, like a classroom in a school or a lecture hall in a university. Historically, most learning and teaching has taken place in this context, largely guided by curriculums, training programmes, and set courses.

From primary school all the way to higher education, traditional learning environments should ensure they empower students with the hard and soft skills needed to enter the labour force and the wider society as adults.

AI as a topic should be introduced to children from a young age. Children must learn what AI is and what it is not early on. With early exposure to AI, children can start investigating real-world applications for the technology.



TESS POSNER
CEO, AI4ALL



“This camp has helped me figure out what I'm passionate about and realize that I truly can make a great contribution to this world.” - 2018 AI4ALL student

AI4ALL is a nonprofit working to make artificial intelligence more diverse and inclusive. A key part of AI4ALL's work is summer programs run in collaboration with major universities where underrepresented high school students get introduced to AI with a focus on social impact, relevance to other topics they already care about, and technical skill building.

Alumni go on to do incredible work in AI. For example, after experiencing the loss of her grandmother due to an ambulance shortage, 16-year-old alum Viansa is working with 2 other alumni to create an AI emergency call ranking system that helps emergency responders make sure the most urgent calls are addressed first. Another alum, 16-year-old alum Stephanie, noticed that the computer science (CS) education opportunities in her agricultural community were sparse.



She created a CS + AI club at her former middle school to introduce young people to AI.

AI4ALL is now expanding this impact through a new Open Learning platform launching in early 2019, which will offer globally accessible AI curricula for free that can be used both online and in the classroom.

Picture Credit: Princeton AI4ALL

More than just teaching students the technical skills needed to build AI, we ought to introduce them to the many social and ethical issues. We need students, across all ages, to understand AI's implications in society.

AI courses, specifically, must consider incorporating these ethical and philosophical aspects within their lesson plans to ensure that the technologies being deployed are socially beneficial.



PROFESSOR JOANNA BRYSON

DEPARTMENT OF COMPUTER SCIENCE,
UNIVERSITY OF BATH

DR. ANDREAS THEODOROU

DEPARTMENT OF COMPUTER
SCIENCE, UNIVERSITY OF BATH



Higher education science and engineering courses, such as Computer Science (CS), often contain entire modules on professional ethics; training future scientists and engineers on how to act within their profession. However, such courses are often restricted to basic legal requirements such as data protection. Recent advances in the field of Artificial Intelligence (AI) make it necessary to expand the scope of how we think about teaching ethics to future software developers. It is becoming increasingly important for students to understand not only how to behave in a professional capacity, but also of the impact that AI and software more generally

has and will have on society. This requires a better understanding of policy, governance, and ethics more broadly.

Computer Science already addresses transparency and safety through courses such as software engineering, which require not only effective documentation, but also procedures for working in teams, with users and non-technical managers and so forth. We should extend such considerations to legal and moral accountability for foreseeable (not just foreseen) consequences of design decisions. This should be a part of all computer science degrees, as machine learning and other aspects of AI are becoming standard programming techniques. Computer Science students, just like those of other disciplines (architecture, civil engineer, medicine, management, even archaeology), need to be trained and perhaps licensed in the safety and societal implications of their designs and implementations.

Effectively communicating ethics as part of a taught science or engineering module requires extensive background knowledge in disciplines many UK students will not have had before A levels, such as philosophy and psychology. While introductory courses in ethics provided by non-CS departments might provide some such background, often these disciplines have little experience with directly building systems. It would be better to develop new courses through interdisciplinary cooperation, providing not only tailored-made courses as part of STEM degrees, but also new content and considerations for the humanities and social sciences.

We conclude with a few general points aimed at policymakers and other stakeholders. These need to understand that AI is not a newly discovered lifeform with necessary human-like properties like ambition. Rather it is the product of deliberate acts of development, and as such something for which humans and human organisations need to be held to full account. This will motivate choices related to transparency so that corporations can prove due diligence when called to account for the consequences of their products. Similarly, the social disruption caused by increasing our intelligence is not a step change but rather a gradual process continuing on from the innovations of rail and telegraph in the 19C. Government policy needs to continue supporting and perhaps extending the safety net of public health and education, as jobs will become more transient though at the same time workers more productive and lives potentially more rich. There are also serious issues of inequality which have not been adequately addressed since 1978, a tragic error given the lessons of 1908-1945.

Finally, the most imminent threat is the deliberate malicious usage AI, which has already opened the doors to population-level manipulations, as well as security risks. It is essential that these be dealt with through truly secure encryption, with no back doors. We cannot and should not ask the public to trust AI when they cannot trust the security of their devices.

Lastly, policymakers should support the investment needed to start integrating AI technologies within classrooms. We already invest in teaching machines how to learn, we need to make sure we invest in teaching our children

Both the delivery and the design of the way individuals learn is transforming. AI has the power to make learning truly personalised. Students can receive a completely custom-made learning experience that fits his or her needs and goals. According to a recent study by Microsoft Education, students who receive personalised instruction perform better than 98% of traditionally taught students.

Big data and AI together can uncover patterns of learning behaviour that can be used to improve the entire learning process and create personalised learning paths for each learner.

AI can be used to measure the skills individuals are good at and make sure their value is recognised. AI can and should also be used to match these skills with opportunities in the labour market and in the society.

**QUALITY LEARNING
CAN BECOME THE
NORM WORLDWIDE.**



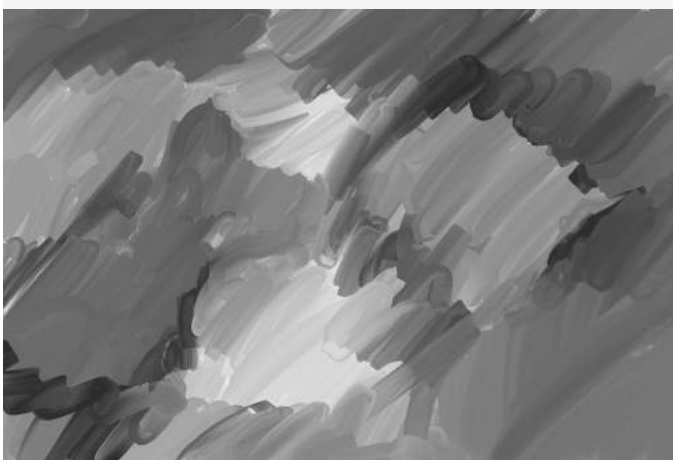
PROFESSOR ROSE LUCKIN
PROFESSOR OF LEARNER CENTRED
DESIGN AT UCL KNOWLEDGE LAB

AI systems can effectively tutor students in well-defined subject areas, such as those that are routinely part of the school, college or university curriculum. These systems can provide highly adaptive and personalized learning tools that help students to gain an understanding of the basics of a subject in a way that suits each individual learner. The AI does not get tired of helping a student go over areas of difficulty time and time again, and the AI can also help students who are able to move forward quickly to progress with speed. In addition to helping students understand the basics, AI can also help them construct the stepping stones on which teachers can build to help students gain a deeper understanding of what knowledge is, where it comes from and how we decide what we do and don't believe.

Examples of such AI software include: Alelo's experiential language learning driven by virtual role play simulations (www.alelo.com), or UK-based Century Tech that uses Machine Learning to

track students' interactions, through mouse movements and each keystroke, to build up a detailed understanding of how each student is progressing that can be shared with teachers, students and parents (www.century.tech). These AI driven educational systems provide an excellent complement to a human teacher's role, which can focus on the teaching and mentoring that cannot be automated through AI.

AI can also help students to develop the important skills and capabilities they will need in the AI augmented workplace. For example, AI can support humans to learn to be better at working together to solve problems, through: adaptive group formation, expert facilitation, virtual agents, and intelligent moderation. See Betty's Brain (www.teachableagents.org), for an example of an AI system that engages students in working together to teach an artificially intelligent virtual student, to understand a misconception.



HOW TO UPSKILL THE WORKPLACE?

The workplace is the second context in which skills can be learned and developed. Socio-technological trends are starting to give this context more importance as the significance of life-long learning and reskilling continuously rise.

Work is changing and, consequently, employees are turning into “learning workers.” In the past, employers wanted workers who could perform manual tasks – known as “manual workers.” Over the centuries, however, this has shifted to employers wanting workers with specific knowledge or expertise – known as “knowledge workers.” Now, we are seeing employers with skills across the spectrum - who can learn and, oftentimes, relearn and unlearn.

21st century employees must have the ability to learn and master new skills. They need to pursue new knowledge and constantly climb up the learning curve.

To empower employees to become these types of workers, the workplace has big responsibility

to upskill and/or reskill its existing and incoming staff.

KPMG have built a pioneering model to help understand how these transformations are unraveling. In collaboration with Imperial College's Data Science Institute, they created the KPMG & Imperial Data Observatory. This investment has been aimed at the need to bridge the gap between raw data, telling a story about the data and visualising data. This is important because visualising data, telling a story about it and engaging in a conversation with the data is the way in which action may then follow.

The Data Observatory enables this. Within the Data Observatory sits a specific application that we call foo.castr (future of organisation caster). This explores the task level impact of AI on jobs. It does this

by looking at HR data at the organisation or function level as well as exploring the nature of tasks within jobs using machine learning. For instance by analysis of job and business process descriptions. This then allows us to see which tasks within jobs may either be fully automated, may allow for accelerated throughput and accuracy or may augment a human by supporting decision making. It is these task-level impacts that require the reinvention of the workforce if productivity gains are sought that we speak about on pages 47 and 38. Visualising the areas of the workforce that will be affected by the different degrees of task level AI impact, both now and in the future, allows C-suite and HR executives to see what choices they need to make about skills, re-skilling and re-shaping the workforce.

Figure 13: Future of Organisation Caster - foo.castr

	Simple Interactions	Basic Problem-Solving (according to rule-base)	More Complex Problem-Solving and Human Augmentation
Routine Tasks	<ul style="list-style-type: none"> • Calculate • Search • Associate 	<ul style="list-style-type: none"> • Report • Reason • Recognise 	<ul style="list-style-type: none"> • Predict • Translate • Diagnose
Non-Routine Tasks	<ul style="list-style-type: none"> • Converse • Categorise • Coordinate 	<ul style="list-style-type: none"> • Decide • Curate • Recommend 	<ul style="list-style-type: none"> • Explain • Investigate • Forget

We see the increasing sophistication of AI having three categories of impact: surviving skills, thriving skills, and shaping skills (Figure 14).

As our world of work changes then so too does our skills agenda.

Skills for surviving with AI, thriving with it so that it makes our work both easier and better and, finally, shaping the world with AI are all going to be key to our future. We see foo.castr at Imperial College as one of the tools that will help us navigate this new skills landscape.

Figure 14: Surviving, Thriving, and Shaping Skills (KPMG)



**ROBERT BOLTON**

PARTNER, KPMG

The impact of AI on organisations and what this means for skills.

As we have already discussed, AI will primarily affect jobs at the task level, not at the level of automating whole jobs. At least not yet. But this task level impact will have a profound impact on the world of work. Indeed, it's already happening. The impact is perhaps best encapsulated by a quote from a senior HR leader at a global bank who said that "the HR function is moving from a world where it used to match people to jobs to a world where it matches skills to tasks." This atomisation of work is occurring in many sectors of the economy including professional services (legal, accounting, consulting) and financial services, particularly insurance and banking. In turn, this atomisation or task level impacts of AI has implications for skills in organisations in addition to the often discussed skills required to work on and manage AI such as data science and algorithm design. These skills are more associated with working with AI.

1). The emergence of 'boundary-less' functions and in time, functionless enterprises

Atomisation of work into tasks opens the possibility of reconfiguring organisations into new forms. Already we are seeing organisations as diverse as professional services, insurance and news gathering describe the evolution of roles as a result of AI. For example, traditional underwriting in insurance can be highly automated by AI but one multi-national insurer described the fact that although they foresaw a reduction in numbers of underwriters, they also described the emergence of a new role that embraced both underwriting and adjacent disciplines such as risk consulting and product development. Similarly, an engineering firm described a new discipline emerging in its business of engineering information integrator. A role which draws on systems thinking disciplines, as well as mindset and connects traditional engineering disciplines underpinned by such technologies as digital twins.

Regardless of whether its functional leaders, such as those running HR, IT and Finance, or professional leaders, such as journalists, medicine, engineering, law or accountancy; they describe similar dynamics at play owing to the way work is changing because of the adoption of AI and related technologies:

Figure 15: Changing Work Dynamics as a Result of AI

- 1** A perceived reduction in numbers employed
- 2** Bigger more systemic and integrating roles for those that remain
- 3** Roles operating in ways that embrace and transcend adjacent functions
- 4** Creating looser more flexible and networked organisation models requiring higher degrees of cross-boundary connection and collaboration: In an organisation where all types of decision makers have access to 'one source of the truth' and where decision making is cognitively enabled by AI; then the disintermediation of judgement making by bridging activities such as can be found in roles that occupy HR, Finance, Procurement and IT soon become obsolete.

In particular, be it HR, Finance, Audit, Underwriting or any other impacted occupation or function, the underlying skill, in addition to the ubiquitous data science skills, is systems thinking. The ability to look at the organisation and its parts as a coherent system and sub systems, seeking to understand the feedback, balancing and reinforcing loops of activity that means that intervening in the system will be subject to the laws of systems dynamics such as easy fixes are likely to lead straight back to an even bigger problem 'downstream'.

2). The need to reinvent work in organisations places a premium on certain enabling skills.

Chief amongst these are:

Figure 16: Top Enabling Skills

- | | | | |
|--|---|---|--|
| 1
Design thinking to redesign processes and customer / employee experience so that AI can be most effectively deployed | 2
Behavioural economics to shape choice architecture for both employees and customers | 3
Innovation skills to provide the core drive to change and reinvent our established ways of doing things | 4
Change leadership so that all employees are engaged in a higher purpose and contribute their strengths and ideas to a common cause |
|--|---|---|--|

Much has been written about all of these skills elsewhere. Particularly what capabilities are required to successfully execute them; but suffice it to say here that productivity gains and the creation of more engaging and decidedly human organisations will require these skills in abundance. Take healthcare as an example. The application of AI to enable diagnoses will not replace doctors, nurses and other healthcare professionals. But it will require patient journeys to be redesigned and the roles of healthcare professionals to be reinvented. The traditional boundaries between professionals will also need to be reconsidered as the task level impact of AI will require such a reconfiguration of roles otherwise there will not be any productivity gains.

The reinvention of work is a once in a lifetime opportunity. Yes AI will have both a disruptive and a disturbing effect on workers. Especially in the short term. But it does offer the opportunity to allow humans to play to their strengths.

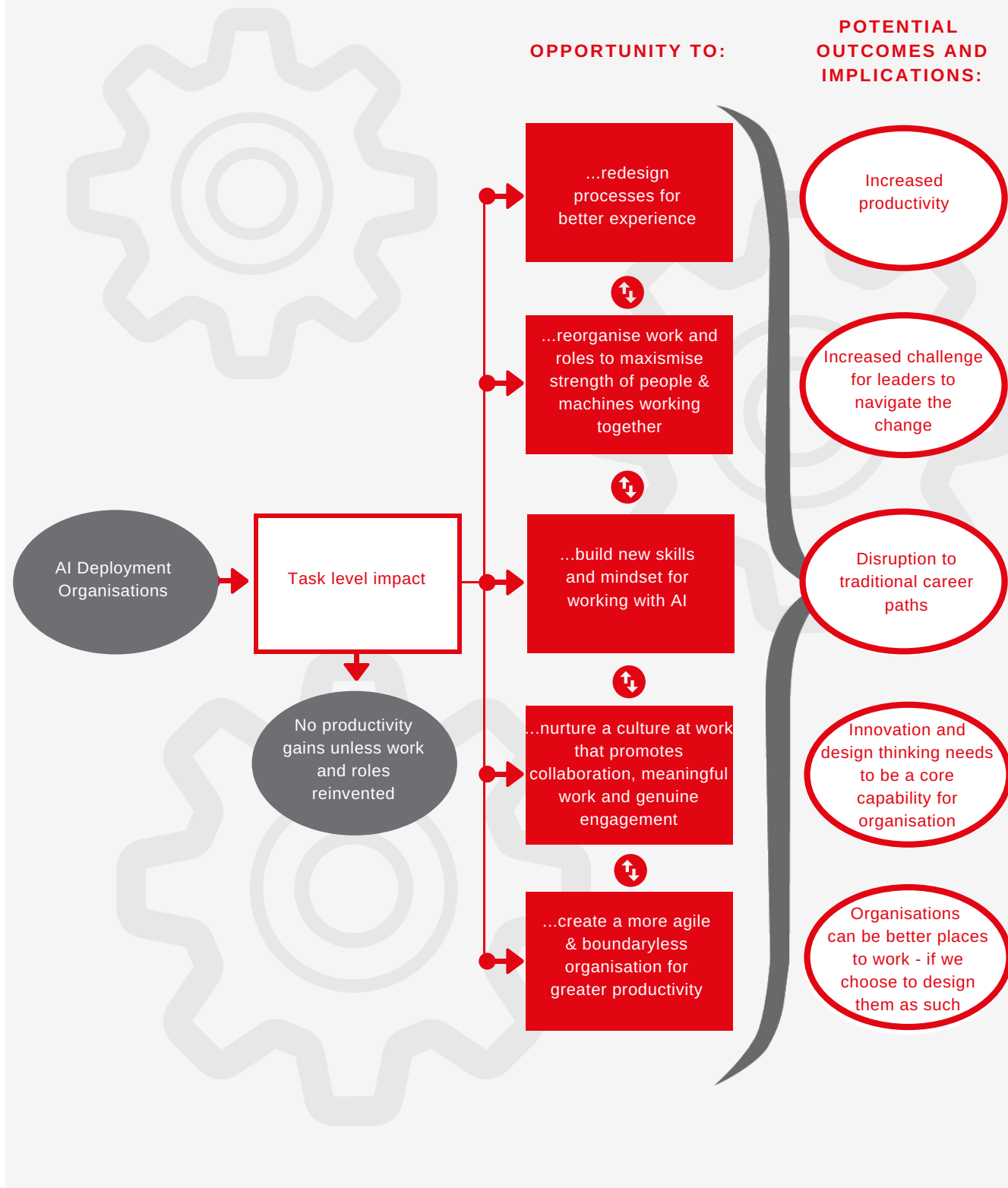
WE CAN CREATE WORKPLACES THAT ARE DECIDEDLY HUMAN WITH SPIRIT AND A DRIVE TO NURTURE OUR PEOPLE TO LIFELONG LEARNING.

AND BECAUSE IT IS SKILLS THAT ORGANISATIONS NEED MATCHED TO TASKS THAT ARE NEEDED AT A POINT IN TIME WE WILL MOVE FROM A WORLD WHERE WE ARE WHAT WE DO TO A WORLD WHERE WE DO WHAT WE ARE.

TO DO THIS WE NEED TO CREATE ORGANISATIONS THAT HELP PEOPLE IDENTIFY THEIR STRENGTHS, GROW AND REINVENT THEM.



Figure 17: The Reinvention of Work Imperative (KPMG)





What we do know at the organisation level is that in spite of billions of pounds of investment in technology in the last 10 years it has not made much of a dent in productivity at the UK economy level, particularly in non-manufacturing sectors. Research with Imperial College at the Imperial and KPMG Data Observatory at the Data Science Institute suggests that the productivity puzzle will continue with the introduction of AI unless we rethink work. Why? Well, it's simple really. AI, at least initially, will affect tasks within jobs, not whole jobs. Therefore, the only way that potentially significant productivity gains will be accessed is if work, processes and organisation are reinvented to realise the potential of the task level impacts; so that machines, humans with machines and humans alone can work in new organisation forms. This is the innovation imperative of modern organisation life but there are early signs that organisation leaders are finally waking up to this imperative. The Economist for example suggested that the productivity paradox might slowly be becoming a thing of the past. Whether there will be less overall work for humans in the future is the subject of much debate and it is not the point of this report to further that debate. As shown recently by MIT, no one can agree on the degree of job reduction or job gains anyway. What we do know, though, is that if organisation leaders rise to the organisation innovation imperative, as a result of their investments in AI, then the impact on skills will also be significant.

In just about any industry one can think of, the use of AI will affect how humans in new roles will need to interact with each other. For example, take healthcare. Around the world, healthcare systems are under intense strain. They need the productivity gains arising from new technologies and AI to bridge the current productivity gap, let alone the growing demands that will be placed on them from older populations. In this scenario they will still need more people working in healthcare but as Mark Britnell, Global Chairman of Infrastructure, Government and Health at KPMG points out in his forthcoming book "Human. Solving the Global Workforce Crisis in Healthcare" on the future of healthcare, they will need different skills, in different roles that relate to each other differently. For example, pharmacists will operate wellness centres, treatment and consultation will move to virtual forms of interaction supported by AI and care pathways will be completely redesigned with the use of cognitive AI augmentation.



What does this mean for skills in health? Well we don't need more of the same in a reinvented workplace. In a world with new clinical pathways, AI enablement and new roles, we need new skills. Moreover, the OECD report 'Health Employment and Economic Growth: An Evidence Base' states that results from the Programme for the International Assessment of Adult Competencies (PIAAC) "shows that a large proportion of doctors and nurses reported being over-skilled or under-skilled for some of the tasks they need to perform. Around 70% of doctors and 80% of nurses reported being over-skilled for some aspects of their work, while about 50% of doctors and 40% of nurses reported being under-skilled for other tasks". As Mark Britnell points out: "Taken as a literal truth, this could suggest that jobs and tasks are so badly designed that they are barely fit for purpose and drag on productivity, create frustration, cause stress and burnout. A more sober analysis of the tasks needed to care for patients over the next decade would strongly suggest a greater need for generalists and peripatetic community workers supported by cognitive assistance, artificial intelligence and robotics. The tribal demarcations between health and social care (in the NHS there are over 300 job types) must give way as clear pathway management will standardise many tasks that will enable new sources of local labour to be employed and drawn from local communities." The thing is, this dynamic that will unfold in health will be repeated in insurance, accountancy, legal, retailing and pretty much any other industry sector you can think of. But if we are to make better places of work for humans, the skills agenda must be addressed.

THE ROAD AHEAD

FORWARD-THINKING, PRIORITISING LEARN TO LEARN



WHY LEARNING TO LEARN?

As AI's impact and implications are starting to be felt, stakeholders worldwide - across governments, businesses, and the wider public - are realising urgent action is needed.

Above all, policymakers have to address how to educate people to be prepared for such rapid changes. Skills are important for individuals, for business, and for society as a whole. For individuals, 21st century skills can help secure

employment and wellbeing. For business, 21st century skills can help boost productivity and efficiency. For society, 21st century skills can increase public impact, reduce welfare dependency, and source higher tax revenues.

SKILLS ACROSS THE HARD SKILLS AND SOFT SKILLS BRACKETS SHOULD BE INCENTIVISED AND REWARDED; BUT, IF WE DO WANT TO FUTURE-PROOF INDIVIDUALS, WE SHOULD PRIORITISE THE SKILL OF LEARNING TO LEARN.

Like AI, learning to learn cannot be easily defined. In short, it can be described as the skill of processing new information into knowledge and/or value; but, furthermore, the skill of learning as a goal rather than just a mean.

The famous saying “Give a man a fish and you can feed him for a day. Teach a man to fish and you can feed him for a lifetime” can help make sense of it.

Revised to fit the modern era, let’s think of it as:

**“GIVE A (WO)MAN
KNOWLEDGE/
INFORMATION AND YOU
CAN FEED HIM/HER FOR A
DAY. TEACH A (WO)MAN
TO LEARN AND YOU CAN
FEED HIM/HER FOR A
LIFETIME.”**

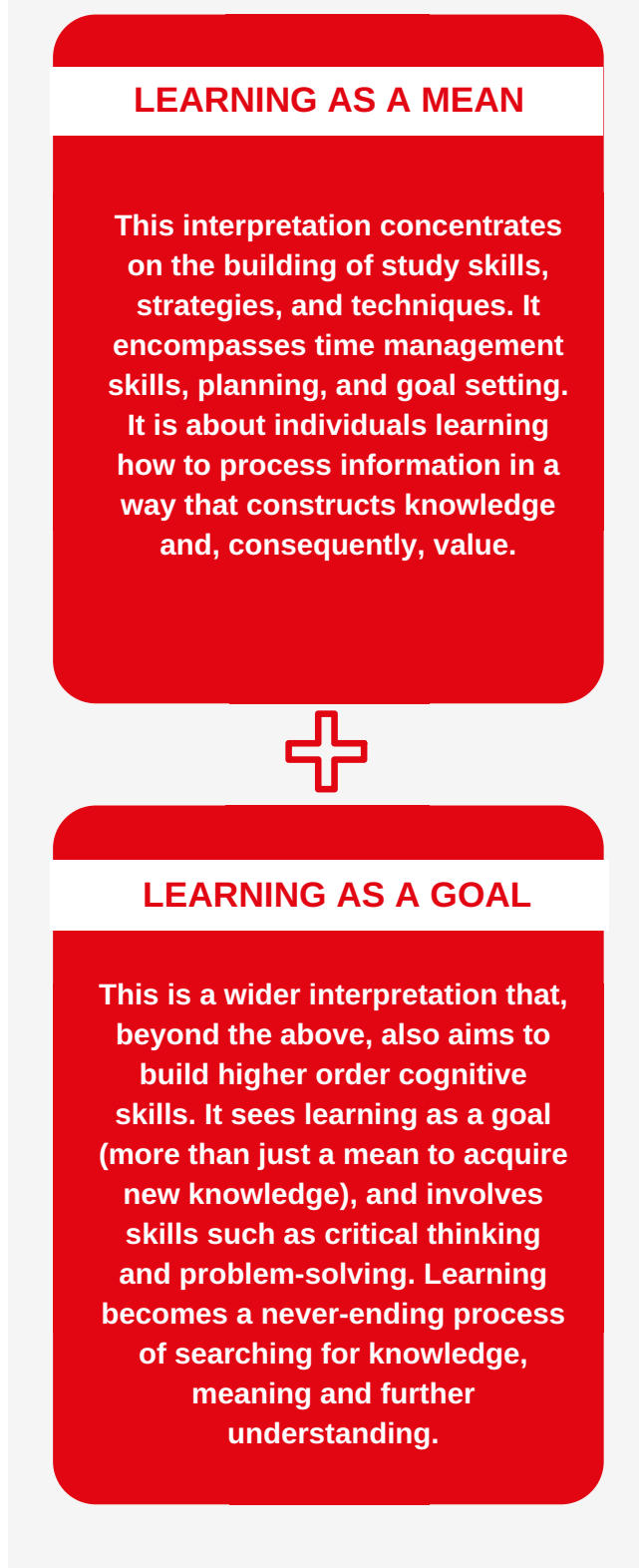


This couldn’t be truer, especially in an increasingly AI-filled society.

This is what learning to learn is all about.

It is twofold (Figure 18).

Figure 18: Learning as a Mean and a Goal





Learning to learn is the skill characterising those with the ability to constantly pursue knowledge and understanding. It is about always asking questions, experimenting with new topics and subjects, and staying curious. It is about learning not because you want to pass an exam or secure a great job but because you want to learn.

**KNOWING HOW TO
LEARN WILL BE
FUNDAMENTAL TO
MEET THE DEMANDS
OF AN
UNPREDICTABLE AND
AGILE WORLD.**

**WE MUST KNOW HOW
TO LEARN, RELEARN
AND UNLEARN
CONTINUOUSLY.**

Younger generations need this skill to be prepared for the uncertainties they will face in their futures. We need to encourage them to develop the drive to learn and incentivise them to pursue it.

In the classroom, learning to learn should be implemented and developed from primary school all the way up to higher education.

The skill of learning to learn can be introduced in two ways: (a) through isolated curriculums with courses and activities aiming to specifically build this skill, or (b) embedded in existing curriculums. To properly embed learning to learn within regular curriculums, teachers must consciously change their assumptions on learning and their actual lesson plans and activities.

Rather than presenting information to students, teachers must help the students develop the skill needed to absorb this information and process it into knowledge for themselves.

However, teaching students how to learn should be thought of as more than helping a student process information, particularly in scenarios where he/she is struggling. It should be thought of as developing a skill of learning to learn, in which students are encouraged to learn for the goal of learning.

Due to limited time and strong pressure for curriculum coverage, teachers have often had to sacrifice teaching students how to learn for teaching them what to learn. AI, nowadays, offers a great opportunity to change this. Serving as aides to teachers in the classroom, AI can help provide teachers with the extra time needed to teach students how to learn and bring back the joy of learning.

Furthermore, AI can help interpret how a student learns best and, hence, provide truly personalised learning tips, strategies and techniques.

AI can help make learning fun, assuring the learning experience

matches the preferences and needs of each student.

The aim is for students from a young age to enjoy learning and become intrinsically interested in equipping themselves with new knowledge and capabilities.

The aim is for students to become eternal learners.

Just like in the classroom, learning to learn has to also embed within the culture of organisations.



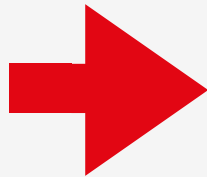
MARTIN ANDERSON
DIRECTOR OF LEARNING
SOLUTIONS, KPMG

The L&D function in organisations has been in a state of flux for years. Whilst its primary purpose of meeting workforce development needs has not altered greatly, the function has had to cope with a plethora of issues all wrapped up with imperatives on skills development and building knowledge, some of these concerned with the theory of learning and how we learn, to others brought about through the adoption of technology.

Broadly this has resulted in an evolution of the function from it being the traditional custodian of the

Figure 19: The Changing Role of the L&D Function in Organisations**Traditionally**

- Custodian of the learning environment
- Reactive provider of training courses

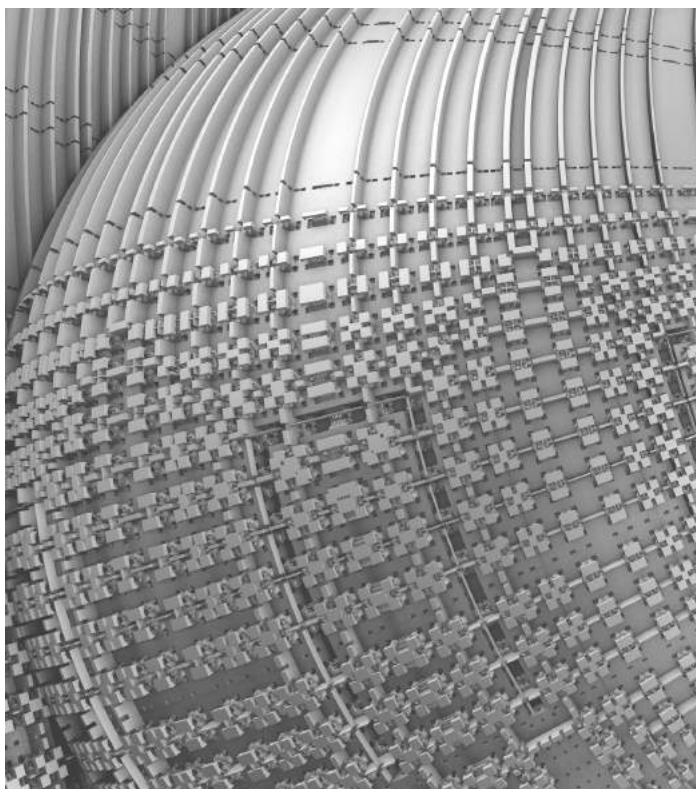
**Now**

- Curator of learning resources
- Producer of personalised learning pathways
- Mapper of skills to tasks

learning environment and reactive provider of training courses to that of being more predictive and the curator of learning resources enabling learners to access and consume what is needed as part of their learner experience. That journey of curation is set to continue as the importance of linking informal, social learning with formal learning experiences increases and individuals find ways to learn for themselves. This will of course in the immediate term demand L&D professionals to be competent in curation and progressively to act more as the conveners or architects of eco-systems to free learners to access the information at the point of need. However as organisations incorporate robotic, human, contingent and gig workers into their resource strategies these diverse supply chains and greater numbers of contingent workers will demand a consistency to up-skilling and training options whilst at the same time working and operating in looser more flexible and networked.

This creates a dichotomy for the L&D function because alongside its role of curator, where presently it synthesises and “joins the dots” releasing learners from systematic curricula to produce their own learning pathways, the function is having to be ever more involved with “the business” as it strengthens links between workforce value and production. And with the atomisation of work comes more focus on matching skills to tasks and that means L&D has to be far more prescriptive and specific in what is supplied for the learner. So on the one hand L&D is acting as the liberator for the learner when at the same time it is having to get really granular and map skills to learning at a task level. AI will become the training assistant in all this, aiding the learner to learn and will contribute to those consistent learning outcomes, for instance there will be routine use of things like situation judgement testing to help point towards development of skills for tasks and to facilitate self organised learning, all of which means ultimately AI takes on the role of curator. organisation models.

The L&D function needs to be mindful that just allowing further evolution of the function will not be enough. It needs to use the opportunity of digital disruption to re-invent the learning organisation to ensure it stays relevant to business by driving deeper employee engagement whilst also providing senior leaders with meaningful data so they can drive the organisation in the right direction.



We have entered a new era of technological change. Huge investments and efforts are needed. We need more people who can build AI, who can work with AI, and who can live in an AI-society. We need to help empower people with the skills needed to survive, to thrive, and to shape their given contexts.

Policymakers, playing an essential role in what our future looks like, must incentivise learning by investing and encouraging personalised learning experiences throughout one's lifetime. The development of skills across the spectrum should be rewarded.



SIR ANTHONY SELDON

**AUTHOR OF THE FOURTH EDUCATION
REVOLUTION AND VICE-CHANCELLOR OF THE
UNIVERSITY OF BUCKINGHAM**

As someone who spent 20 years as the head of two of the country's top academic schools, and the last three years as head of the university which comes top of the government's teaching excellence framework, I have no pleasure in recording that neither government nor parliament comprehends at all the full impact of AI on education.

Education is truly the Cinderella area for AI. Government understands the impact of AI on a range of other areas including transport and medicine, and we urgently need to address the deficiency for education.

AI profoundly change the way that teaching will take place in the future.

It will also profoundly change the required skills that we are educating our students for, the society in which they will live, and the mental world in which they will inhabit.

We are educating our young to become more like machines, like robots; but digital technology and AI machines will always outperform us. Instead we need to be educating our young to become more fully human.

In my book 'The Fourth Education Revolution - will AI liberate or infantilise humanity', I argue that AI is utterly unlike any other technological revolution over the last 500 years.

The future is already happening in schools and universities across the world. All schools and summit public schools in the United States give students their personalised learning programmes at the start of each day. Students move at their own pace in each and every subject receiving personalised learning beyond the ability of any school at present to deliver. The current crisis in specialist teachers is in Science and Mathematics, especially in the more disadvantaged areas of the country, will be addressed by this new technology.

Our fundamentally passive, obsessively cognitive model of education is meaning that we are sleep walking into a world in which AI will impoverish rather than enrich all our lives.



**TO BENEFIT FROM THE
OPPORTUNITIES AI POSES
AND TO PROTECT
OURSELVES FROM THE
HAZARDS, WE MUST
PREPARE AND EMPOWER
OURSELVES WITH THE
SKILLS WE WILL NEED TO
SURVIVE AND THRIVE.**

Future citizens and future employees must be equipped with the skill of learning to learn in order to work and live in the world unfolding - one of constant transformations.

ACKNOWLEDGMENTS

TO THOSE WHO MADE THIS REPORT HAPPEN

Big Innovation Centre is grateful to KPMG for sponsoring this project and for their invaluable input.

Special thanks to:

- Robert Bolton, Partner and Head of People & Change Global Centre of Excellence, KPMG
- Shamus Rae, Partner and Head of Digital Disruption, KPMG
- Martin Anderson, Director of Learning Solutions, KPMG
- Chris Barkataki, Workforce Intelligence UK Lead, KPMG
- Mark Kennedy, Director of the KPMG Centre for Business Analytics, Imperial Business School

We also are thankful for the contributions from: Sir Anthony Seldon, Professor Rose Luckin, Professor Margaret Boden, Professor Joanna Bryson, Dr. Andreas Theodorou, Professor Jonathan Seville, Jonnie Penn, Kevin Green, Tess Posner and more.

Lastly, this report could not happen without the work of the All Party Parliamentary Group on AI and, particularly our Chairs, Stephen Metcalfe MP and Lord Clement-Jones.



AUTHOR

NIKI ILIADIS

INNOVATION AND POLICY FORESIGHT MANAGER,
BIG INNOVATION CENTRE

Niki leads the delivery of the APPG AI, exploring the intersection of technology, policy, education, and philosophy.

REFERENCES

MORE READS

- **AI in the UK: ready, willing, and able?** Lords Select Committee on AI.
<https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/100.pdf>
- **AI Sector Deal.** BEIS and DCMS.
<https://www.gov.uk/government/publications/artificial-intelligence-sector-deal/ai-sector-deal>
- **APPG AI Findings 2017.** Big Innovation Centre
http://www.appg-ai.org/wp-content/uploads/2017/12/appgai_2017_findings.pdf
- **Artificial Intelligence and Life in 2030.** Stanford University.
https://ai100.stanford.edu/sites/default/files/ai100report10032016fnl_singles.pdf
- **Computing Machinery and Intelligence.** A.M. Turing
<https://www.csee.umbc.edu/courses/471/papers/turing.pdf>
- **Growing the Artificial Intelligence Industry in the UK.** UK Independent Review.
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/652097/Growing_the_artificial_intelligence_industry_in_the_UK.pdf
- **Register of All Party Parliamentary Group on AI.** APPG AI
<https://publications.parliament.uk/pa/cm/cmallparty/180131/artificial-intelligence.htm>
- **What is AI? APPG AI Theme Report 1.** Big Innovation Centre.
http://www.appg-ai.org/wp-content/uploads/2017/03/themereport1_20mar-1.pdf
- **The Fourth Education Revolution: Will AI liberate or infantilise humanity?** Sir Anthony Seldon
- **Year of Engineering.** HM Government
<https://www.yearofengineering.gov.uk/about>

A report created by **Big Innovation Centre**, the Secretariat for the **All-Party Parliamentary Group on AI**, and powered by **KPMG**.

www.biginnovationcentre.com |  @BigInnovCentre
www.appg-ai.org |  @APPG_AI

Big Innovation Centre | 8th floor Penthouse, 20 Victoria Street, London SW1H 0NF
All Party Parliamentary Group on Artificial Intelligence (APPG AI) Secretariat
T +44 (0)20 3713 4036
Written By: Niki Iliadis | Email: n.iliadis@biginnovationcentre.com

© Big Innovation Centre 2018. All rights reserved

