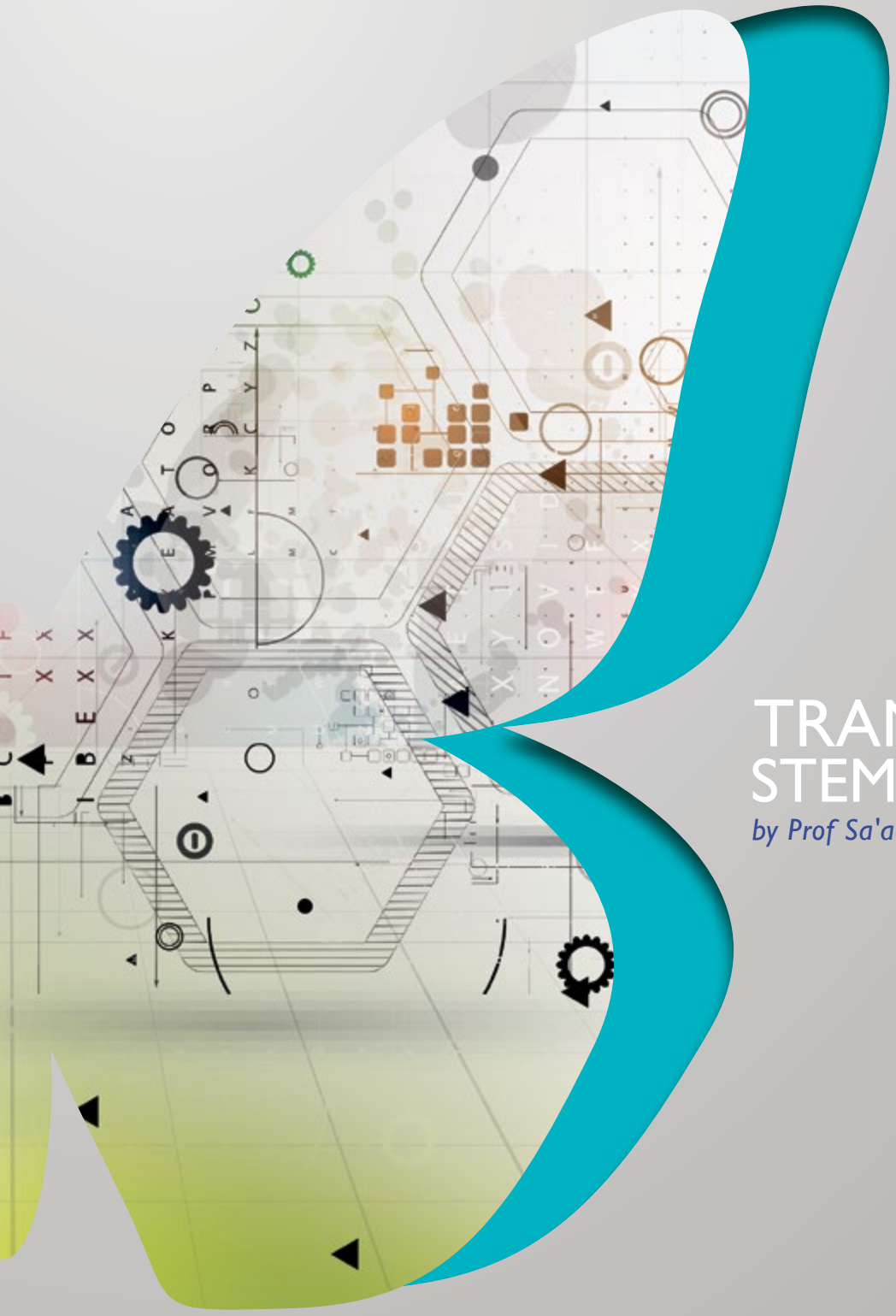
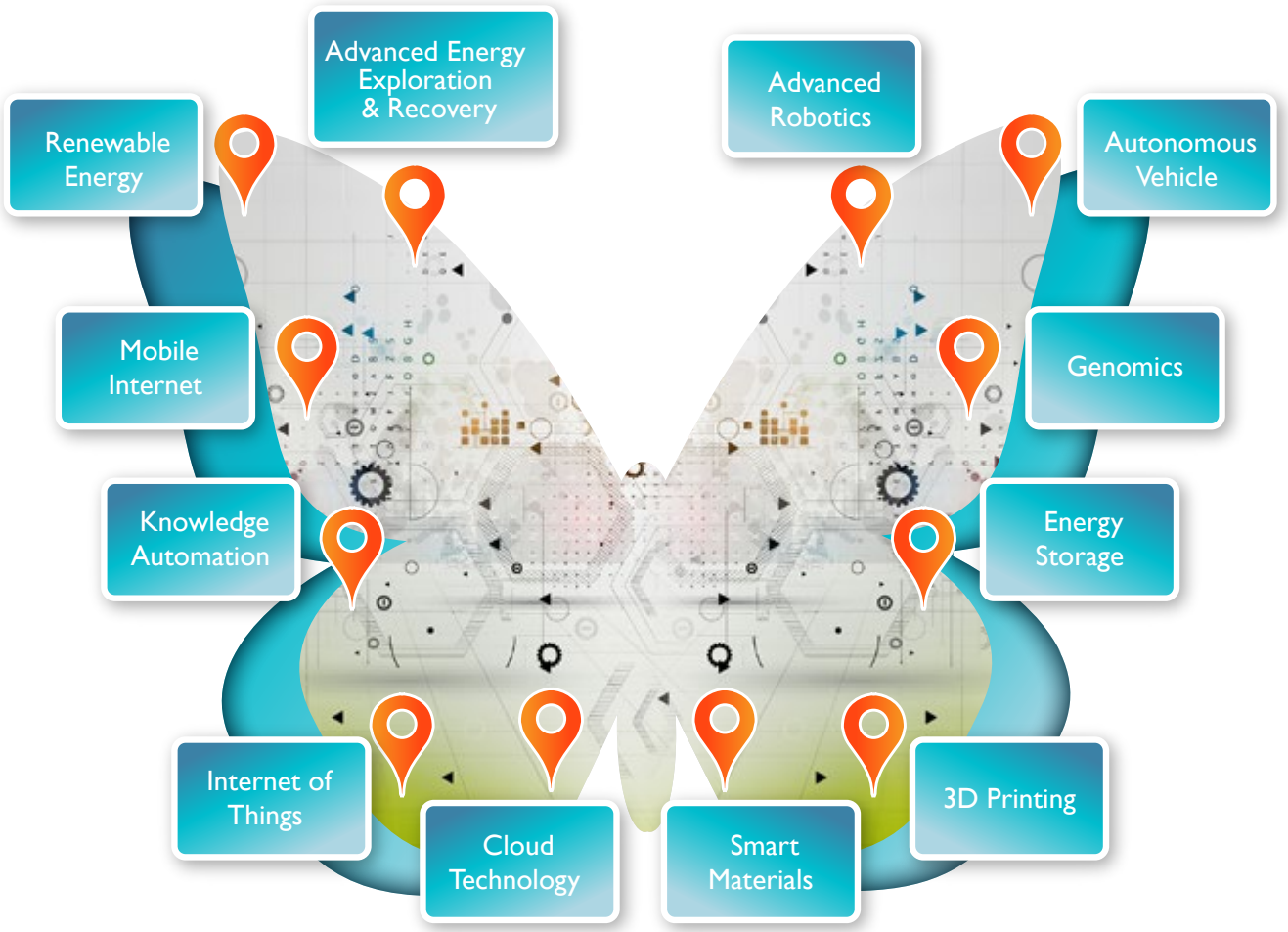
INVENTING THE FUTURE



TRANSFORMING STEM ECONOMIES

by Prof Sa'ad Medhat

NEF
The Innovation Institute



INVENTING THE FUTURE

TRANSFORMING STEM ECONOMIES

A think tank report by
NEF: The Innovation Institute
July 2014

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FOREWORD

Baroness Verma, Under Secretary of State for Energy and Climate Change

We face many challenges in the 21st century, from ensuring the security of our energy and food supplies, to reducing carbon dioxide emissions to safeguarding our environment against climate change.

Technology offers great potential in helping us meet these challenges: enabling the creation of smarter, carbon neutral buildings or innovative transport solutions; facilitating advances in medicine and manufacturing.

Innovation and new scientific disciplines such as biotechnology and nanotechnology are beginning to transform our social and economic landscape at a hitherto unprecedented rate. They are also radically changing the kind of skills required for the workplace: new occupations are emerging that will generate wealth whilst some traditional roles will become redundant.

Our role as Government is to ensure the availability of future technology options, reduce risk, provide mechanisms that support market growth and, where necessary, facilitate conditions to create new markets.

Whilst there are many opportunities, we are already facing great shortages within STEM (science, technology, engineering and mathematics) occupations. This requires a shift in our culture and in our thinking, and I think it's very important that we communicate the vital importance and exciting possibilities within future STEM careers to the next generations of learners.

At DECC we are working on the kind of skills that engineers that we will need in the future and considering how we could adopt and build on transitional skills from other sectors.

If we are to create multidisciplined technologists who can assist us in fields ranging from advanced manufacturing, to energy and environmental technology to cyber security, there is much work to be done. This paper explores how Government, businesses, educational providers and other stakeholders can collaborate together to create a vision for a more flexible and innovative workforce.

We are already facing great shortages within STEM occupations. This requires a shift in our culture and our thinking

Baroness Verma
Under Secretary of State for Energy and Climate Change

The availability of multidisciplined technologists will be pivotal for supporting a culture of innovation and ensuring that UK companies remain competitive.

I'm very keen to encourage a more diverse representation in STEM subjects. Attracting a wider demographic into the sciences will be critical for introducing new ways of thinking and paving the way for more imaginative approaches to the world's greatest challenges.

INTRODUCTION

Gavin Patterson, Chief Executive Officer, BT Group

Looking at the world today, you could be forgiven for thinking that innovation is easy and inevitable. Devices get more powerful. Connectivity reaches ever further. Speeds get quicker. Data gets bigger. It's all too easy to think that the next innovations – say, the internet of things or smart cities – will just come along as a matter of course.

At BT we know that the truth is, of course, very different. We are the world's oldest telecoms company and our purpose, which has fundamentally been the same for 160 years, is to use the power of communications to make a better world. We were there when the world's first telegraph networks were built and the first wireless transatlantic call was made. We invented the world's first electronic programmable computer and helped pioneer the fibre optics that underpin today's globally connected world. We know that constant innovation takes commitment and cultivation. And as different technologies converge, and the boundaries between disciplines blur, this is more important than ever.

To keep innovations coming, three things are essential:

Serious investment Research isn't predictable. It needs the time and space for exploration, for following hunches, for going up many blind alleys, and running with wild ideas. At BT, we've invested in innovation for over 160 years (£3.1bn in the last five years in fact and the latest EU report ranks us in the top three of all UK companies for R&D spend over that period). But the real key to our track record of innovation has been that this investment is constant.

Constant innovation takes commitment and cultivation. As different technologies converge, this is more important than ever

Gavin Patterson
CEO, BT Group

Imaginative partnerships Innovation has always thrived at the edges and intersections – where disciplines can spark off each other and cross-fertilise. We make sure we're always collaborating right across the globe. We're connected to universities, labs and hot spots such as Silicon Valley, Cambridge and London Tech City. And at our engineering headquarters in Suffolk we've co-located sixty high-tech companies, large and small, on one of the largest innovation campuses in the UK.

A culture of inspiration When a business has its roots in innovation, you need to promote a culture that embodies that spirit. Which means you need a diverse mix of talent – from the academically excellent to apprentices and practitioners. And you need to encourage them to be entrepreneurial, try new things, make mistakes and learn from them. At BT our new ideas scheme provides tools, systems and processes to empower colleagues to act on their ideas. And to inspire the next generation, we also have a schools engagement programme to help excite young people about STEM subjects, rather than see them as 'difficult' and something to fear.

These are extraordinarily exciting times. But if we are to be part of them, we need to make sure we cultivate the right conditions for talent to thrive. Only then can we play our part in inventing the future.


ABB Robotics


Marshall ADG


Cobham

A MESSAGE FROM OUR SPONSOR

STEM skills are crucial for economic growth; the UK's current challenge is ensuring that enough talent is graduating with skills that are relevant to current and future industry requirements. I believe that a fundamental step in providing a long-term solution to skills shortages is to align future industry needs with FE and HE strategy. This NEF report is a reflection of industry sentiment; the proposals could be the catalyst for a step-change in STEM education.

Our involvement with the NEF supports our desire to maintain a broad understanding of the issues affecting the industry today, utilise our reach to develop solutions and take action. The report's recommendations are groundbreaking and deliberately challenging in order to provide a sustainable long-term solution for the skills gap challenge.

Keith Lewis, Managing Director, Matchtech

matchtech®

IT'S TIME TO CONNECT

Prof Sa'ad Medhat, Chief Executive, NEF: The Innovation Institute

Before you begin reading *Inventing the Future*, let me start with a warning. This report may make for uncomfortable reading. It calls for wholesale restructuring of STEM provision in the UK, as well as a radical rethink of how industry and education providers collaborate.

Breaking down traditional boundaries, changing communication channels and opening up academic silos is not going to be easy, but if we are to stimulate innovation and economic growth there has never been a greater urgency for action.

Technology is disrupting virtually every aspect of life and work, from 3D printing, cloud computing and advanced robotics to biotechnology and human genomics.

This is a dramatic change, and it calls for a more flexible and agile workforce, able to move between various disciplines. And therein lies the problem: our education, funding and qualifications systems are still constricted by academic boundaries that were established decades or even centuries ago. Despite the obvious enthusiasm and dedication of teachers and lecturers, out-dated skills are still taught in the classroom. New technology is often ignored.

In preparing this paper, NEF consulted with companies of all ages and sizes: from multinational corporations with decades of expertise, to fresh young start ups launching cutting edge innovations. A common thread emerged from our discussions: there is a profound disconnect between what STEM-based companies require in terms of skills; the technological changes that they see on the horizon and what many further and higher education institutions currently provide.

We need to pave the way for vibrant technology clusters throughout the UK

Prof Sa'ad Medhat
Chief Executive, NEF: The Innovation Institute

There has been extensive discussion about STEM skills shortages in recent years. But most of the thinking around this issue is desperately short term, based on the immediate and visible needs of companies. *Inventing the Future* is calling for a longer term approach: giving students the competencies and confidence to move between sectors in a rapidly changing employment landscape.

Ever since NEF was formed in 2004, we have been working hard to create stronger connections between industry and education. We have engaged more than 500 companies, supported more than 250 FE providers and worked with more than 70 colleges to develop coherent STEM strategies.

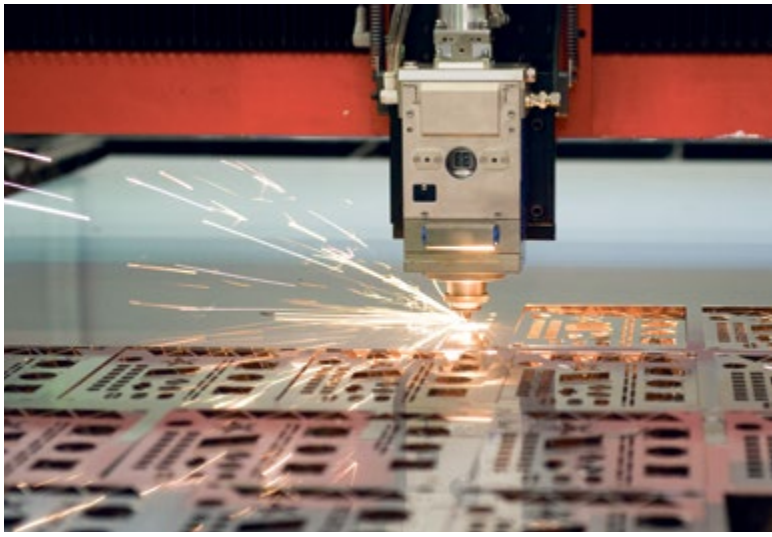
But it has become increasingly clear that changing individual institutions is not enough. This is why we are asking all stakeholders – colleges, universities, multinationals, charities, Government, Local Enterprise Partnerships, city councils and SMEs - to come together, and to take greater ownership of coordinated skills provision across the regions; paving the way for vibrant technology clusters throughout the UK.

I would like to thank to everyone from industry, education and Government that has contributed to this paper, in particular, Baroness Verma, BT CEO Gavin Patterson and our sponsor Matchtech.

This is just the beginning. Please help us continue the debate.

EXECUTIVE SUMMARY

The world of work



- The world of work is changing, and the pace of change is accelerating. The internet of things and cloud computing have transformed many industries. In coming decades areas such as robotics, digital fabrication, biotechnology and genomics will further revolutionise the way we live and work
- The boundaries between traditional sciences are dissolving: the most exciting innovations are taking place at the interface of different disciplines, such as nanotechnology and biomimetics
- Having a strong culture of innovation is essential for economic growth, it is also important for helping us develop approaches for the major challenges of the 21st century, such as the reduction of carbon emissions, increased urbanisation and safeguarding our towns and cities against climate change
- To meet these challenges, it is important to develop technologists that are flexible, can collaborate and have multi-disciplinary skills[1]
- With the rapid proliferation of new technologies, this poses an enormous challenge for our education system: how do we prepare students in a landscape that is constantly evolving, for a future that is difficult to predict?
- The UK ignores these educational challenges at its economic peril: the global race to lead innovation is hotting up, placing a high demand on technical skills
- Manufacturers around the world are increasingly adopting disruptive technology and scouring the world for the most innovative workers

The skills shortage: current situation

- The skills gap continues to widen in the UK. In a recent CBI survey, **42%** of respondents stated that recent engineering, IT and technical recruits did not meet reasonable expectations for levels of skill
- In the NEF's Think Tank survey, conducted in spring 2014, only **16%** of STEM-based companies (companies heavily reliant on the disciplines of science, technology, engineering and mathematics) said that their skills needs were fully being met. A worrying **32%** reported that finding people with the right skills was a serious struggle
- Recruiter Matchtech reports a shortage across most STEM disciplines. There is international competition to attract the best specialists in areas such as automotive engineering and aviation
- Companies are often reluctant to take on graduates without any practical experience and/or have to undertake extensive retraining to make newcomers ready for industry

Industry feedback

- Industry feedback, across many sectors, suggests that further and higher educational institutions are too focused on immediate and short term skills requirements
- STEM-sector companies specify degrees (or similar) as a minimum entry requirement. Yet many graduates are ill-equipped for the workplace

[1] This was highlighted by *The Future of Work: Jobs and Skills in 2030* by the UK Commission for Employment and Skills (UKCES) February 2014

Skills and qualities that companies are looking for:

- Flexibility: the ability to adapt to changing technology
- Interoperability: the ability to apply STEM knowledge and skills to different sectors and contexts
- A broad understanding of how STEM skills can be applied across a range of sectors and within a variety of markets
- The ability to innovate and invent
- An understanding that they may have a variety of different job roles and work in several industries over their career
- An entrepreneurial mindset: whether for working within large organisations or launching their own start-up companies, industry newcomers need to think laterally and spot new product opportunities
- The ability to combine STEM-skills with other highly valuable competencies, in particular: project management, collaboration skills and interdisciplinary team working
- Skills in data management and data modelling
- Knowledge of international legislation
- Technical writing
- Financial acumen and fundraising skills
- Business development skills
- An awareness of presentation and how to communicate ideas
- An understanding of how to build relationships with customers, clients and stakeholders

Some specific examples of trends that education providers should be adapting to include:

- Building Information Management (BIM) systems for the construction and civil engineering projects
- The development of composites in the automotive, aerospace and marine sectors
- The growing demand for technically proficient project managers within most sectors
- The shift in emphasis from networks and systems to applications in information technology
- The widespread call for newcomers to have wider skills in areas such as people management, customer relationship management and design

The education system: current limitations

- NEF has carried out a three-year study of further education colleges and found that STEM provision was inadequate in virtually every case. **In the worst examples, 80% of a curriculum was 'misaligned'**(it did not match industry trends)
- The educational provider's offer is too embedded within traditional disciplines and training silos:
    - The cross-curricula nature of learning is still very limited
    - Qualifications and methods of measuring capability are restrictive and outdated
- The perceived **value** of STEM-based education has been steadily eroded over the past few years. Trust is breaking down between parties: companies doubt that they can recruit people with the right skills. Learners worry whether their overall training and experience will give them **employability**
- Employer-run academies are a growing trend: some companies have very specific needs that cannot be met by traditional syllabuses
- Whilst employer-run training academies undoubtedly train up to a high standard, one downside is that the learner remains immersed within a traditional technical silo or sector – he or she does not learn to work across different sectors and disciplines
- Apprenticeship courses are inflexible and variable in quality – there is no consistent national standard

The way forward

In order to increase productivity of individuals or companies, it is necessary to increase the skill level both of the existing workforce and of industry newcomers. Valuable time and money could be saved by creating a pipeline of workers that have relevant practical and technical skills from the outset.

Too much focus is currently placed on recruiting graduates, even if they are ill prepared for industry.

Alongside universities, further and higher educational institutions could play a more pivotal role in developing technicians and technologists who could be ready for industry in a shorter space of time.

To better serve the needs of the market place the NEF recommends restructuring of STEM education in order to address skills provision at every level of competency:

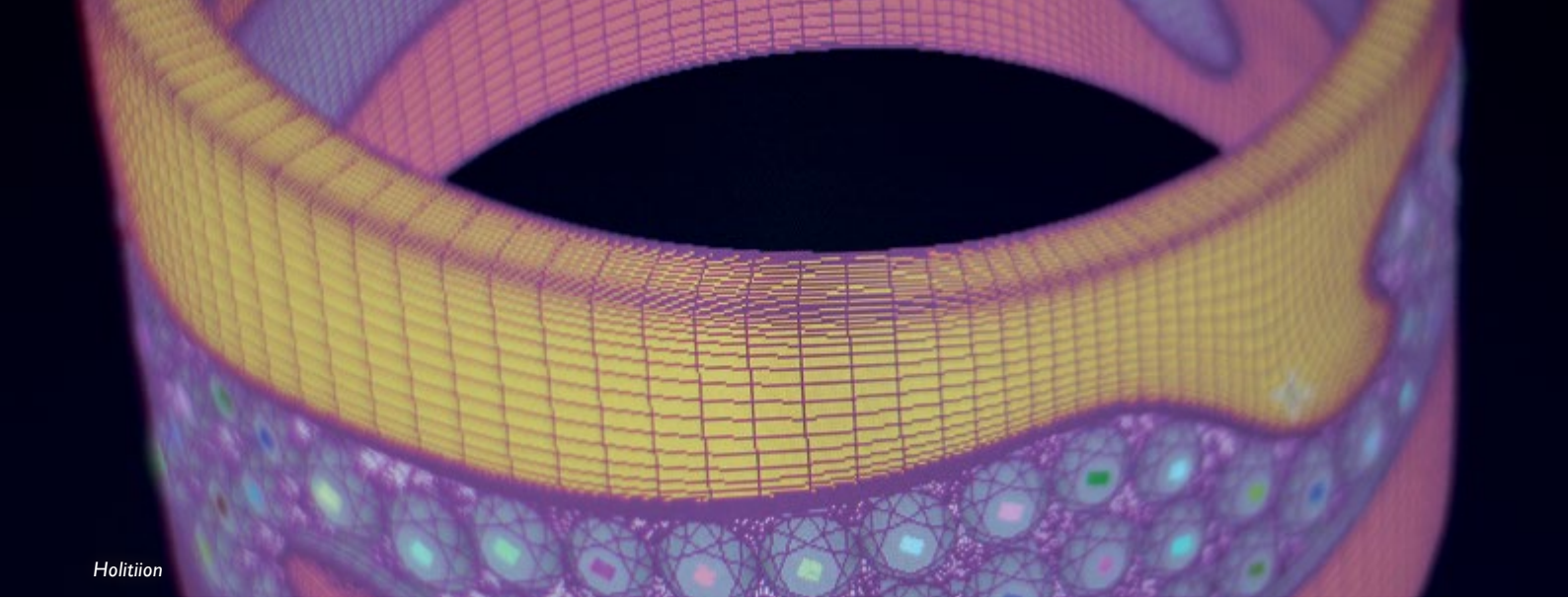
- **Community education centres** whose purpose is to drive social development and inclusion, raising the skill levels of technicians and providing fit-for-purpose courses that enable the learner to enter the workforce directly. Companies' corporate social responsibility (CSR) remit could play a key role in supporting such centres
- **Regional polytechnics with vertically integrated educational provision**: these new style polytechnics will focus on building growth and productivity within a particular region. They will accept learners from the age of 14, offering courses that encompass all levels of professional development

The principles of the regional polytechnics

- **A curriculum that is not fixed, but evolves to keep pace with changing trends and technology**
- **Courses will be open and flexible:** catering both for students that want to follow a full curriculum, and workers who want to top up their knowledge with individual modules
- **Students** are engaged as **active partners** in **collaborative learning**
- **Lecturers** will assume the role of coaches rather than teachers, charged with improving the educational offer
- Applied research and learning transfer will encourage **interoperability of skills** across multiple sectors: technologists will develop core competencies that enable them to move confidently from one sector to another, with a minimum of additional training investment
- **The polytechnic will act and behave as an innovation hub,** carrying out applied research that will benefit companies in the region. It will **innovate and collaborate with industry stakeholders** in an inclusive and open manner

Design for learning

- Study in the classroom or workshop should be **tailored to the needs of individual students**
- STEM courses should be **cross curricular** - not separated into narrow academic silos
- Students should take **creative ownership** of the learning process
- There should be a significant emphasis on creating an **interactive learning environment** using tools such as **augmented reality software**
- Learning should be placed into **context** so that students understand how they can apply their knowledge to different sectors



Holitiion

THE CHANGING WORLD

Preparing for a fast and unpredictable future

Android developer. Data scientist. User interface designer. Big data architect. Cloud services specialist. These roles barely existed in 2008. Today they are some of the fastest proliferating job titles among LinkedIn's 250 million users.[2]

The world of work is changing, and the pace of change is accelerating. The internet of things and cloud computing have transformed many industries. In coming decades areas such as robotics, digital fabrication and biotechnology will further revolutionise the way we live and work.

DNA research is already driving great advances in medicine. Next generation genomics will enable us to manipulate human genes, tackling genetic diseases that were previously thought to be incurable.

Advances in genomics will also create opportunities to help us improve the performance of agriculture and to create high-value substances — for example ethanol and biodiesel — from ordinary organisms, such as E. coli bacteria.[3]

Forecasts of the future can only be tentative: it will be some years before we fully understand the effect of disruptive technology in the workplace and on society. And new technologies may quickly replace those that seem radical today.

But one thing is certain: occupations will change at an ever increasing rate: new roles will be created whilst others will become obsolete.

This poses an enormous challenge for our education system. The debate on how to make vocational and technical courses more relevant to industry is aired on a regular basis. But this is being eclipsed by a much bigger question: how do we prepare our students for a future that nobody can predict? How do we create a generation of workers that are flexible, adaptable, and inventive?

It is a question that we ignore at our economic peril: in the future, the most robust supply chains, most vibrant regions and the countries with the fastest growing GDP will be those that actively encourage and nurture innovation.

Competition to attract and retain the best talent now encompasses the developing and developed world. The increasingly mobile international workforce will travel to where the salaries and opportunities are greatest.

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[2] LinkedIn Talent Blog, *Top 10 job titles that barely existed five years ago*, Sohan Murthy, 6, Jan 2014

[3] *Disruptive technologies: Advances that will transform life, business, and the global economy*, James Manyika, Michael Chui, Jacques Bughin, Richard Dobbs, Peter Bisson, and Alex Marrs, May 2013

Countries across the globe are striving to find solutions to the major challenges of the 21st Century. Those regions that innovate most successfully will also export their expertise in tackling areas such as:

- Combating pollution
- Reducing dependency on fossil fuels
- Conserving dwindling natural resources
- Creating smarter cities
- Dealing with more extreme weather events
- Coping with increasingly dense living conditions in cities

Whatever their stage of economic development, governments are placing an increasingly high value on STEM education as a means of encouraging innovation, increasing national living standards, protecting existing industries and encouraging new ones.

For example:

- The national Government of India is aiming to produce 500 million skilled workers by 2022. At present, the country's current formal vocational education and training system only has capacity for three million. The potential for social transformation is enormous: Today, more Indians have a mobile phone than access to proper sanitation
- In South Korea, advances in education, particularly tertiary education, have played a significant role in the country's economic growth since 1960. Today, roughly two thirds of South Korea's output growth can be attributed to knowledge accumulation rather than labour or capital. The country now shares a similar challenge to many of its neighbours as well as countries in the West: how to sustain or accelerate growth as the population stabilises and ages
- In 2013, the US National Governors Association (NGA) released a guide, Building a Science, Technology, Engineering, and Math Education Agenda, focused on strengthening STEM education The NGA proposes that economic growth will be driven by the USA's ability to generate ideas and translate them into innovative products and services. The key action is to increase the number of students who pursue advanced studies in STEM
- In a bid to arrest the disturbing trend of mass graduate unemployment, Nigeria's Federal Government is promoting entrepreneurial education in its tertiary educational institutions as a means of equipping graduates to function as job and wealth creators rather than job seekers
- Recovering from the horrors of war, the Rwandan Government has introduced a series of reforms to the country's technical and vocational education and training system, the main thrust of its policy to end poverty
- The 2012 World Bank report, *Skills, Not Just Diplomas*, focusing on education in Eastern Europe and Central Asia, calls for a closer relationship between education, and the needs of employers. The report also recognises a wider economic need for entrepreneurs

There are already examples of "technological leapfrogging" taking place in developing countries, where traditional phases of development are skipped in favour of new technology.

Africa's mobile phone market is now the second largest in the world. In 2012, around 54% of the continent's population was reported to have a mobile phone. This has given rise to a number of digital innovations, from mobile banking to the empowerment of farmers with real-time crop information. At a grass roots level, Ushahidi – an open source software platform for the collection of information, visualisation and interactive mapping, through crowd sourcing, was developed in Kenya in 2008, following post election unrest. Its use is spreading throughout the world.[4]

Wherever they are in the world, smart manufacturers are increasingly interested in investing in 'breakthrough' or 'disruptive' innovation alongside efforts to enhance existing product lines. In KPMG's *Global Manufacturing Outlook Survey* for 2014, 36% of respondents said that they were now focused on breakthrough innovation compared to just 31% of respondents the previous year.

"Technological leapfrogging" is taking place in developing countries, where traditional development phases are skipped in favour of new technology

Within the same survey, more than eight out of ten manufacturers reported that 3D printing was already impacting on productivity.[5]

It led Jeff Dobbs, KPMG's global sector chair of manufacturing to comment:

"The manufacturing world is entering an era of hyper-innovation where advances in technology and material science are rapidly changing what we consider 'possible' and creating new business opportunities along the way. Ultimately those organisations that do not balance investment in 'incremental innovation' with investment in 'breakthrough innovation' may find themselves left behind technologically."[6]

In the UK, the Government has defined priority funding for eight technology areas[7] which, it believes, will propel the UK to future growth: big data; space; robotics and autonomous systems; synthetic biology; regenerative medicine; agri-science; advanced materials and energy.

If we are to harness the full potential of all these sectors, we need to develop a more versatile and agile workforce able to collaborate across different disciplines.

This paper sets out to discover how we can best prepare the STEM workers of tomorrow for the visible and unforeseeable challenges ahead.

THE GOALS OF THIS PAPER ARE

- **To get a sense of how STEM-based companies see the future**
- **To pave the way for a more effective transfer of knowledge between industry and education, particularly at technical and vocational level**
- **To explore the qualities and attributes that technologists of the future need to develop**
- **To examine how local and national government funding can support the process**

[4] Carlo Ratti, director of SENSEable City Laboratory at MIT's Department of Urban Studies and Planning, World Economic Forum blog, 9 May 2014

[5] *Global Manufacturing Outlook: Performance in the crosshairs,* KPMG, published 14 May 2014. Based on a survey of 460 senior representatives of the aerospace and defence, automotive, conglomerates, consumer products, engineering and industrial products and metals sectors

[6] *Ibid*

[7] *Investing in Research, Development and Innovation*. Department of Business, Innovation and Skills, 9 October 2013

SOME VIEWS OF THE FUTURE

ROBOTS ARE MOVING INTO OUR LIVES

Prof Tony Belpaeme

Any predictions about the future have to come with a caveat: nobody really knows what will happen. This is particularly true for robotics: a myriad of exciting possibilities are opening up both for the home and the workplace, but whether they reach their full potential depends not only on technology, but equally on legislation, political will and attitudes within society.

One area that is causing a lot of excitement is the driverless car. We already have cars that can park themselves. Developments in 'assisted driving' will continue to evolve. As most car crashes are due to human error, cars that automatically brake to avoid hazards could save hundreds of thousands of lives globally.

On the domestic front, autonomous vacuum cleaners are already available, but in the future, far more sophisticated robots could become commonplace at home, particularly helping to care for the elderly population.

A trial is already underway under the ROBOT-ERA research project using robots that can distribute meals and remove rubbish in block of flats. In the future robots could assist elderly people who live alone, reminding them to drink water or to take medicine, helping them dress or wash, or moving them up and down stairs.

Telepresence robots, effectively a kind of Skype on wheels, could be operated remotely by carers or concerned relatives, moving through the apartment to check that there are no problems, beaming back pictures in real time and facilitating conversations between the resident and the relative. If robots could support independent living, delaying people moving into care homes by as little as a year, this could bring powerful benefits both for the economy and society as a whole.

Robots could also be used in the health sector to complement the work of physiotherapists, aiding rehabilitation programs. At Plymouth University we have been involved in a project with the San Rafaelle hospital in Milan to help a young boy, partially paralysed after a stroke, to learn how to move again. After six weeks of physiotherapy, the boy spent several days with a small companion robot that motivated him to move. The boy made a full recovery. He was walking and lifting his arm within a week of meeting the robot.

Robotic technology could soon be adopted by many sectors, the advent of drones for delivery or surveying work has been well publicised. Drones are also being used to check assets on building projects; in agriculture, work is underway to develop intelligent robots that can move along fields, selecting which crops are ready to harvest.

Our sector needs systems engineers that combine a general understanding both of electro-mechanical engineering and software programming. But we also need scientists proficient in new disciplines such as pattern recognition or computer vision. This is the clever technology that can analyse data produced by cameras attached to robots, interpreting what they are 'seeing', helping them to navigate and make decisions about their environment.

There is still an immense amount of work to do before the full potential of robots can be realised. Robots do repetitive tasks in factories very well, but are still clumsy when handling random tasks. Developing sophisticated robotic arms and hands is a major task ahead for our sector.

Microsoft CEO Bill Gates has predicted that robot technology will cause the next major revolution for consumers in the same way that the personal computer did three decades ago. If the robotic market is to follow the personal computer or mobile phone model, there will be an enormous requirement for technicians in manufacturing, software programming and in retail and repair shops.

There is also immense scope for innovation at grassroots level. French company Aldebaran Robotics is encouraging consumers to develop apps for its humanoid robots. Developing apps in this field will be a growing trend.

If the UK is to encourage home grown talent in this field, computer programming needs to be taught in much more detail at all levels of education. Coding is not that difficult a concept to grasp, and children should become comfortable with the basics at primary school.

Tony Belpaeme is Professor of Cognitive Systems and Robotics at Plymouth University

TECHNOLOGY IS TRANSFORMING TRADITIONAL JOBS

Chris Yapp

The boundary around the digital skills sector is widening considerably. In the future, it is hard to think of jobs that will not require a good grounding in IT and better maths competency, whether they involve using productivity tools in the office, building apps or managing vast amounts of data.

Artificial intelligence is increasingly outperforming humans in areas such as medical diagnostics or legal opinion. It is encroaching into areas that were once the domain of highly qualified and specialised people. The disruptive effect of technology on employment in these sectors will be the equivalent of introducing automation into factories.

Technology is facilitating different ways of working: accountants can now use specialised software to carry out real time audits of a company's accounts. In construction, the technology going into smart buildings is as complex as that of a Boeing airplane. Designing secure and robust systems to process building data will be a major challenge.

Tech jobs in the intermediate future could include creating apps for the internet of things, for example, the ability to control household appliances (such as heating thermostats) remotely over the internet, or developing applications for wearable health monitors.

It is likely that the majority of IT work in the UK will focus on software rather than hardware development. But because technology is changing so fast, predicting more than a few months ahead is precarious. Many people see apps as the future, but app sales are already declining, and it is unclear whether they will be replaced by something else in the medium term. We have very choppy times ahead until we understand the full implications of cloud-based technology.

There is a permanent shortage of programme and project managers as well as system engineers in the tech sector. But if we want to be serious about the quality of our workforce, we have to do something serious about the quality of our maths teaching at every level of education. We also need to think hard about the type of maths modules that we teach.

In the future, countless jobs previously described as arts or media based will require a solid grounding in maths: this is already true at gaming companies where graphic designers need strong grasp of geometry in addition to an aesthetic understanding of form and colour.

British students are often at a disadvantage compared to their foreign peers: Japanese school children are taught statistics from an early age. In this country the subject isn't studied in depth until A-level.

Technology is changing so rapidly, we have to adopt an entirely different attitude to education. The days when students learned all the skills they needed on a two or three year training course are long behind us. Workers will need to undertake short courses every year, not only to keep pace with new technology, but to adapt to the changing demands of the workplace.

Independent consultant Chris Yapp has a 30 year background in the IT industry and has advised central and local government in the UK and EU on tech matters. A Fellow of the BCS, The Chartered Institute of IT, he blogs on future implications of technology

THE DAWN OF THE CITIZEN SCIENTIST

Melissa Sterry

Population, migration, density, and the urban infrastructure issues, have been issues of significant concern since the mid 17th century. However, as extreme weather, resource shortages and biodiversity loss manifest - and do so at scale - designing resilient cities has become an issue of paramount societal concern. Much focus is placed on training the young to meet the challenges of tomorrow, but we should not underestimate the powerful role that older and more experienced workers can play in STEM-based innovation. City design is a highly complex area, requiring fusion of many different disciplines. Some of the most influential and imaginative pioneers in this field have previously worked in a variety of different STEM and non STEM-based careers. Dr. Rachel Armstrong - one of the most respected and influential experts in living architecture - has also been a medical doctor, science fiction author and chemist.

If we open up STEM training to all levels and ages of society, we could potentially empower the many, rather than the few, to develop new careers, and to do so at any point in their life.

Open access science courses, as provided by institutions such as MIT, Harvard and Open University are growing in popularity and could provide an interesting entry point for amateur scientists. Participants could also become more involved in citizen science projects, helping to collect information and data that could contribute towards major studies, and particularly those of national and global interest.

As the cost of retraining is a major deterrent for many people who may be interested in switching to a STEM career, providing free courses could help to attract a much wider demographic into the traditionally male dominated sector, including more women and ethnic minorities.

However, the gulf between amateur scientist and entry to a PhD programme, or its equivalent, is a very wide one, and this gap would need to be bridged by a comprehensive program of interim STEM training opportunities, where students take on more complex tasks, earning points towards a higher STEM qualification. In expanding the routes to becoming a STEM professional, we not only empower citizens to fulfil their personal potential, but we empower the nation, and the world, as we unleash talent that is currently lying dormant.

Design scientist and futurist Melissa Sterry is a champion of new science, technology and thinking that serves to make the world a better place. Her work is concerned with developing a vision of what successful change may look like and supporting others on a journey towards it

THE UK: SETTING THE SCENE

Concern about the UK skills gap in science, technology, engineering and mathematics subjects has been generating discussion and debate among industry and academic bodies for decades.

Here are some recent comments.

"CBI survey evidence from 2013 suggested that among businesses seeking employees with STEM skills and knowledge, 39% faced difficulties recruiting those staff at some level. Given that our data comes from summer 2013, before the sustained upturn in the labour market... it is likely that these issues have worsened since the economy began to improve."

Engineering our Future:
Stepping up the urgency on STEM
Confederation of British Industry, March 2014

"The skills gap appears to be bigger than ever with 42% of respondents having stated that recent engineering, IT and technical recruits did not meet reasonable expectations for levels of skill.

"...23% said that the shortfall in skill mainly relates to lack of practical experience. The results also indicate a decline of satisfactory numeracy and literacy skills which is a cause for concern.

"...31% of companies said that they did not expect to be able to recruit suitably qualified engineers, IT staff and technicians over the next five years."

The Institution of Engineering and Technology's *Skills & Demand in Industry survey*, 2013.

NEF THINK TANK SURVEY, APRIL 2014

In the NEF's Think Tank survey, only **16%** of STEM-based companies said that their skills needs were fully being met. A worrying **32%** reported that finding people with the right skills was a serious struggle.

"We are finding it increasingly difficult to recruit skilled personnel. Some vacancies are taking months to fill, so our apprenticeship programme is vital to the continued growth of the company.

"There is a complete disconnect between academic study and what industry requires. There is a lack of information and guidance for young people to be enthused by engineering."

SME Manufacturer

THE RECRUITER'S VIEW

Keith Lewis, Managing Director, Matchtech

At present there is a well-documented skills shortage for STEM careers across the UK, with the resource of appropriately skilled candidates consistently falling short of industry demand. This recruitment challenge is further exacerbated by the increase in demand for experienced, specialist engineers for which current STEM education does not provide for. There is an urgent industry need to build a sustainable pipeline of engineering talent, whose training embraces evolving technologies and future advancements in engineering.

Frequently, our recruitment search extends across international boundaries, in order to capture global talent to meet demand for UK engineering vacancies; key to this method is the versatility of engineering skill sets across continents and this transferability is a highly desirable feature to employers. However, it is worth remembering that there is an equal battle between attracting overseas talent and ensuring that the UK retains the resources it has.

The following current trends have been recognised in a variety of UK industry sectors;

- The automotive sector is particularly vibrant in the UK, but the shortage of skilled engineers is creating challenges for companies of all sizes, from SMEs to OEMs, that could impact upon long-term productivity as well as expansion in a buoyant market. For pioneers of new technologies such as hybrid vehicles, electric cars or hydrogen fuel cells, finding engineers with an appropriate skill set is an even greater challenge, and formal education for these may not yet exist. Engineers often have to undertake further industry training in order to work within emerging technologies, which shifts the responsibility of education to industry.

- A number of major infrastructure programmes are due to move into the design stage over the year ahead and so there is a rapidly increasing demand for BIM technicians, for which the talent pool is limited. There is also a particularly acute shortage of signalling engineers; recruitment in this field is fiercely competitive as trained signallers are in high demand on projects such as the Doha Metro in Qatar and the Riyadh Metro in Saudi Arabia, where UK-based signalling systems are being installed.

- Matchtech recently conducted a large scale survey of the marine offshore oil and gas sector and findings indicated that 92% of companies were struggling to recruit people with the right skills. In order to meet the UK's offshore renewables requirement, specialist cabling engineers are being brought in from Germany and Denmark. Offering the highest average salaries, oil and gas companies have started to recruit and re-train engineers from other industries with transferrable disciplines.

Recently qualified graduates sometimes find it difficult to get a foothold into organisations; whilst they may have a strong grounding in technical knowledge; their competencies are often considered to be too narrow and academic. Organisations have also expressed nervousness about investing in internal training for industry newcomers: once a new recruit is truly ready for the workplace, he or she is in danger of being poached by a competitor.

The misalignment between industry skills demand and current education provision is a long term challenge; a solution will require joint action from industry, education and government in order to create a system where future industry skills needs are predicted and satisfied through a more proactive approach.

Engineering recruitment specialist Matchtech is the largest division of Matchtech Group Plc. The Group also provides a specialist recruitment service for the technology sector through its affiliate company, Connectus. Keith Lewis, has 25 years' experience within the recruitment industry, working in both the UK and the USA. His main areas of industry specialism are within: engineering, energy, marine, aerospace, automotive, infrastructure and science.

WORKERS OF THE FUTURE

In this report, the term "technologist" is being used in the broadest possible sense. It refers to workers of any STEM discipline, from engineering to biotech, and indicates a high level of technical competency, ideally in more than one STEM area, combined with a range of transferrable professional and personal skills

Technologists that can innovate

The skills debate frequently lapses into the quality of graduates and the needs of specific sectors. This focus is dangerously narrow: it undervalues the powerful role that technical skills and technical-grade qualifications could play in the future success of STEM industries.

It also ignores the fact that the most exciting areas of innovation today are occurring not within the boundaries of traditional science but at the interface of different disciplines. Having workers that are flexible and adaptable, with the skills that transcend traditional sectors, will be critical for many companies in the medium and long term.

NEF talked to more than 100 companies, ranging from global corporations to SMEs, to discuss their skills needs and hear their predictions for the future. The following section explores some of their forecasts, challenges and predicaments.

CASE STUDY

ROLLS-ROYCE

Rolls-Royce provides integrated power solutions for customers in civil and defence aerospace, marine and energy markets - supporting customers through a worldwide network of offices, manufacturing and service facilities.

Precise and safety-conscious manufacturing is paramount to the company's processes both internally and across its supply chain: roughly one third of all planes in operation contain Rolls-Royce engines. Within each engine, more than 70% of parts are manufactured by supply chain partners.

"We expect everyone in our organisation to focus on continual process improvement, driving efficiencies and raising quality wherever possible.

"Our supply chain also needs to prepare for change, to adapt to new types of materials, such as composites. And there are likely to be many more materials innovations coming shortly that haven't been predicted.

"We take on roughly 700 trainees annually throughout our global network and work closely with colleges throughout Europe. In our experience, educational institutions can sometimes be too limited in their outlook: they focus too much on traditional learning and do not recognise the pivotal role that they could play in liaising with employers, ensuring that they are developing the right skills for industry."

Graham Schuhmacher MBE, Head of Learning Services, Rolls-Royce

CASE STUDY

COBHAM

Celebrating its 80th anniversary in 2014, Cobham is evolving from an aerospace and defence company – and a world leader in air-to-air refuelling - into a global technology business.

Cobham focuses on providing innovative technologies and services to solve challenging problems in harsh environments across commercial, defence and security markets. From deep space to the depths of the ocean, the company is specialising in meeting the growing demand for communications and connectivity.

"A common factor across all markets and applications is the need to drive reductions in size, weight and power consumption or SWaP, which is why Cobham continues to strengthen its capabilities across a range of disciplines, from technologists to supply chain specialists and project managers.

"Employing more than 10,000 people on five continents, Cobham has grown organically and through the acquisition of some 50 companies in the past decade. So our employees also need to be adept in the so called softer skill areas such as partnership building, client engagement and communications."

Julian Hellebrand FIKE, Executive Vice President, Lifecycle and Programme Management, Cobham plc

CASE STUDY

COSTAIN

Costain is a leading engineering solutions provider, active in the highway, rail, airport, power, nuclear, oil and gas, water and waste sectors.

The company works closely with its clients to find innovative engineering solutions for a multitude of challenges including: the projected closure of 300 landfill sites by 2020; a 55GW energy gap; rail freight doubling by 2030; increasing road congestion; nuclear decommissioning and the resilience of the water supply.

Costain instils an innovative approach throughout its workforce, a programme of continuous learning is in place to help employees adapt to changing technology. Incentives are also offered to encourage employees to come up with radical ideas for new and disruptive technology.

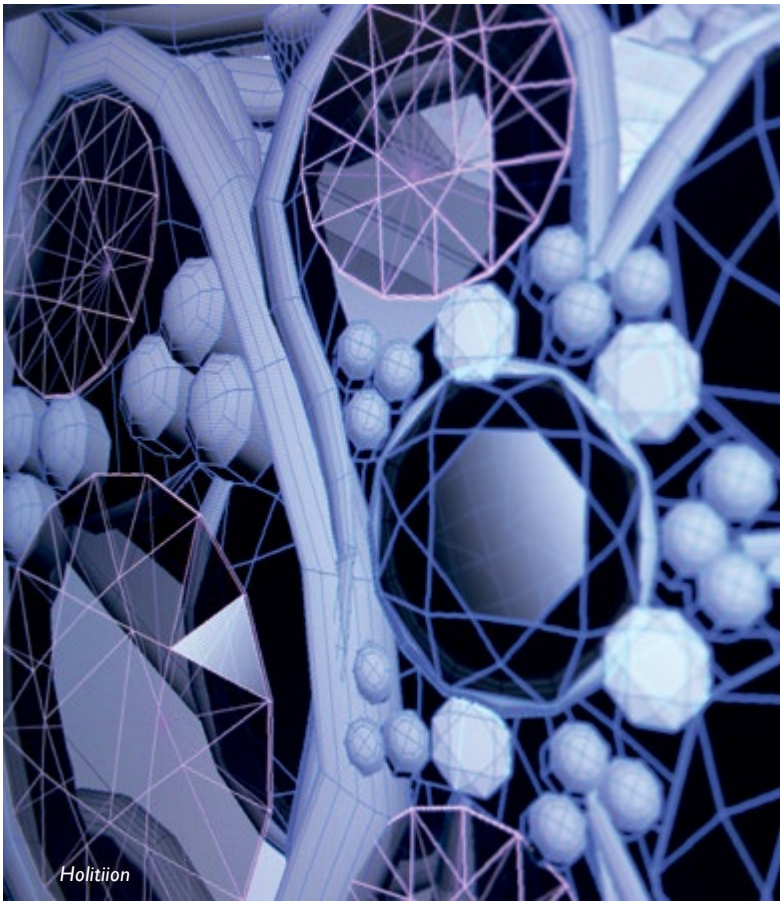
Historically, Costain's recruitment focussed primarily on civil engineering graduates. The company is now looking for a wider range of skills, including technicians that can think creatively and understand the economics of the projects and sectors in which they work.

Across the built environment sector there is an emerging future skills gap in engineering design, as well as a fast-growing demand for those with building information modelling (BIM) skills. From 2016 BIM will become mandatory on all public sector built environment projects across the European Union.

The global hunt for talent is intensifying. For technology-driven companies such as Raytheon, recruiting sufficient numbers of software and systems engineers is an ongoing challenge. We also predict a growing shortage of cyber security experts over the medium term

We welcome the NEF's Inventing the Future Initiative as an opportunity to develop meaningful engagement with further education institutions. A coherent, nationwide technical training strategy is essential if we are to develop a steady supply of well rounded, technically advanced recruits with the right blend of collaborative and leadership skills

Dr Brooke Hoskins
Director of Strategy, Government Relations and Programme Leadership, Raytheon UK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CASE STUDY

EXTRINSICA GLOBAL

Extrinsica Global is a rapidly growing organisation and an early pioneer of cloud-based technology. The company provides bespoke, integrated services to a wide variety of international customers. Recent clients include the FIFA world cup security team in South Africa; oil rigs in the Niger Delta and ships crossing the Indian Ocean.

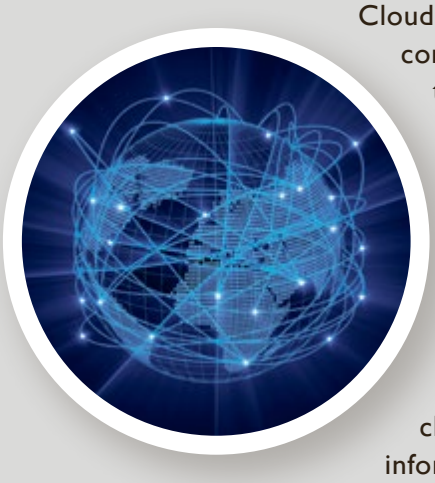
Constant innovation is essential in this rapidly evolving sector. The company has a director of innovation, and encourages a strongly competitive internal environment.

Younger graduates, having grown up with mobile gadgets, can make a valuable contribution to product development. However, education is not keeping pace with technology. University courses also do not place enough emphasis on app development. Extrinsica also reports a shortage of system engineers.

Although technicians often have a strong knowledge base, they do not have the skills to think more broadly about the future. Finding graduates that can think creatively is a major focus of the company's recruitment strategy.

CASE STUDY

EMC²



Cloud Computing services provider EMC², is a global brand that helps companies to store, manage, protect and analyse data in an agile, trusted and cost-efficient way.

The company's client base includes private and public sector organisations in a wide range of sectors including finance, manufacturing, healthcare, life sciences, telecommunications, transport and education.

Innovation in this fast evolving market is focused on improving the speed and quantity of data management. As the cloud expands and its capacities are understood more clearly, information management technologies are evolving on an almost daily basis. There is a strong drive towards automation and, where once the focus was on developing hardware, it is increasingly the software that acts as the market differentiator, adding value for the customer.

EMC²'s skills requirements fall into two broad categories: workers who can find new ways of managing enormous quantities of data; and technologists that can liaise with customers, providing engagement, operational guidance and support.

In this company sales technologists - sellers with a strong technical background – play a vital role: not only in educating and reassuring customers on the safety of EMC²'s storage and handling systems, but also in understanding how demand for data management services is changing. This valuable knowledge can then be used for new product development.

CASE STUDY

ATKINS

Design, engineering and project management consultancy Atkins employs around 10,000 people in the UK and a further 8,000 abroad.

Atkins tackles technically challenging and time-critical infrastructure projects across key sectors including energy; water, urban regeneration, education; geotechnical; rail; highways and airports.

The consultancy's Futures Team examines long term environmental and population trends, forecasting their impact on the built and natural environment and proposing possible solutions. Recent publications include *Future Proofing Cities*.

Atkins reports that, as projects are becoming increasingly complex, teams are developing 'systems engineering' into a more holistic approach: infrastructure engineering which involves different disciplines collaborating closely together, for example through building information modelling (BIM).

Project managers require an understanding of broad sector-wide issues, as well as drawing on a solid foundation of technical knowledge.

MARSHALL AEROSPACE AND DEFENCE GROUP

Marshall Aerospace and Defence Group is a leading independent aerospace and defence company specialising in the conversion, modification, maintenance and support of military and commercial aircraft.

Founded at the dawn of the commercial flight era, Marshall has been constantly evolving to meet the needs of its customers throughout its 104 year history. The deep-seated streak of innovation that runs through the company has been key in helping Marshall break into new markets, open up new territories and achieve technological breakthroughs.

Collaborating closely with OEMs, Marshall has pioneered the increase of composites in aircraft design over recent years. The company's investment in this area has helped bring the technology to market and is now supporting the growth of advanced composites in the sector.

As Marshall converts, modifies, maintains and supports different types and sizes of aircraft of varying ages, staff have to understand and have the qualifications to work both on existing and emerging technologies.

Like many other STEM-based industries, Marshall has always recruited technicians with advanced skills, most notably engineers that can also design. Its successful apprenticeship programme has been running for 94 years. Today, four members of the board including Chief Executive Steve Fitz-Gerald began their careers as apprentices.

"It is the knowledge, skills and experience that make Marshall - we have over 18,584 years of long service. Investing in our people is key to our continued success and we recognise that everyone has an important role to play.

"It is vital that the education system keeps up with the pace of change. Sometimes training mechanisms struggle to keep pace; especially in newer technologies such as advanced composites.

"For young people, relevant and practical experience gained through the educational system is essential. When educational contact is limited, that has an impact. In some cases we have to supplement with in-house training."

David Swann, Foundation Degree Programme Manager, Marshall AeroAcademy

CASE STUDY

DUPONT

"In the future, research will increasingly be carried out at small to nanoscale level. Classical disciplines such as chemical engineering are likely to shift focus from large scale to smaller scale systems such as cells, tissues, or supramolecular structures. We anticipate a proliferation of new specialisms, particularly within the relatively young areas of bio- or material sciences, where several major discoveries have yet to be made. Plant and animal genetics, genomics and related disciplines are evolving fast.

"New disciplines are likely to grow out of the interface between different specialisms, for example the merging of biology and informatics which has led to the interdisciplinary field of bioinformatics. The convergence of scientific disciplines is likely to provide major opportunities for discoveries and innovation in the next five to ten years.

"With the growth in integrated sciences, the boundaries of traditional scientific job roles are likely to become much more blurred. The need for a more interdisciplinary approach will create demand for individuals who can think and bridge across different science and technology domains."

Dr Simone Arizzi, Technology and Innovation Director EMEA, DuPont de Nemours International

CASE STUDY

E.ON UK

E.ON is one of the world's leading power and gas providers, employing around 11,000 people in the UK and more than 62,000 worldwide.

The company's generation portfolio includes gas, coal and biomass-fired power stations. E.ON is the UK market leader in combined heat and power.

E.ON supplies power and gas to around five million domestic, small and medium-sized enterprise and industrial customers in the UK and offers innovative services and technologies to help customers become more energy efficient.

"The UK faces a major challenge as we seek to reduce emissions whilst ensuring that electricity supplies remain secure and affordable for customers.

"Emerging technologies present a range of opportunities to help us meet this head on. Smart meters are being rolled out across the country and households and communities are also beginning to embrace distributed generation, for example where micro generators such as combined heat and power plants or small-scale wind generators attach to distribution networks. In the future increasing numbers of hybrid cars will need a grid to plug into.

"The entire energy industry is also facing another challenge; an ageing highly skilled workforce. Without the right investment in training and skills we could fail to combat the loss of critical business knowledge, and miss the opportunity to build capacity in the supply chain. Ultimately, a more collaborative approach is needed between industry, educational providers and Government, to identify the future needs of the sector and develop a sustainable training programme that meets these challenges. We all must play our part and at E.ON we are firmly committed to doing just that."

David Hughes, Head of Engineering Academy, E.ON

CASE STUDY

BASF

Global chemical giant BASF employs around 3,000 people in the UK, and the company's UK activities include products for agriculture, water treatment and pest control, as well as high grade chemical manufacturing. BASF often recruits students that have completed sandwich degree courses and therefore have some industry experience. But newcomers are often lacking in important skills such as scientific writing, communication skills and creative working.

"Graduates are often very good at their own specialism, but are unable to develop ideas laterally across specialisms, often due to inexperience. We need people who can think in an innovative and strategic way across different aspects of the business. For example, in helping us develop new consultancy services to add value to both our own and our customers' businesses. This requires new thinking.

"One of our biggest challenges in the medium term is finding people that can write technical bio-dossiers for our new product portfolio. This requires several competencies: a good understanding of European legislation and the ability to interpret complex data must be backed by strong technical writing, which is not something that is generally taught to undergraduates.

"At a more senior management level, we need strategic thinkers who understand the impact of technological and legislative changes, who are able to put a project together and attract internal support, presenting ideas in a clear and concise way and demonstrating inspiring leadership."

Dr Rosie Bryson FIKE, Team Leader - Arable Crops – Fungicides, BASF and Chair of the IKE.

CASE STUDY

HINDSIGHT SOFTWARE

Hindsight Software is the leading independent software vendor of behaviour driven development (BDD) tools. BDD is an analysis technique for discovering and communicating software requirements between business stakeholders and software developers, a common point of failure in many projects.

In the two years since the company was founded, Hindsight has developed an internationally leading tool for agile requirements specification and a verification tool for the retail banking, e-commerce and health technology sectors. The company currently employs four full-time and three part-time staff and runs apprenticeships in software engineering.

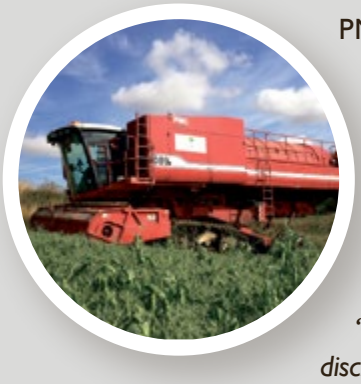
"There is an ongoing shortage of skills in computer programming, software testing and people with problem-solving skills. The education system is not meeting all of our needs. For example, test driven development, a standard industry technique for non-safety-critical systems, seems to be unheard of in college and university courses. Students are too frequently "spoonfed" with information and are unable to break down problems into manageable chunks and solve them on their own.

"As university graduates seem to have the same technical skills as 16 year olds, we have started to run apprenticeship schemes for school and college leavers. Our apprentices go through the same training programme that we run for graduates. In this way we can ensure that we are developing the most viable skills as quickly and efficiently as possible without having to unteach graduates."

Dr Alan Parkinson, CEO and co-founder, Hindsight Software Ltd

CASE STUDY

PMC HARVESTERS



PMC Harvesters has been manufacturing pea and bean harvesters at Fakenham, Norfolk, since 1970. The company employs approximately 40 people. As well as manufacturing, it also provides maintenance services.

Over the years, PMC's products have become increasingly reliant on IT. All the machines are controlled by microprocessors. GPS systems are fitted to the higher specification models.

"As well as specialists, we need people with a broad-based understanding of several disciplines. Our computer programmers need to understand how hydraulics work. The hydraulics engineers have to comprehend how their parts fit with the control systems. And whilst we don't manufacture the GPS parts, our engineers must grasp how they can be integrated in the machines.

"Most of our employees are trained to HNC level, but we have to carry out a lot of additional training because we work in a niche area. Engineering education is such a broad-based spectrum; no college can offer what we want. We really struggle to meet our skills requirements as there are very few electro-hydraulics courses. In the last two years we have been taking on apprentices. However, we are finding that providers of good quality engineering apprenticeships are disappearing from our area. Our local industrial training centre is closing down this summer, and our apprentices will have to travel further afield to continue their training."

Robert Plant, Engineering Manager and Julian Smith, Manufacturing Manager PMC Harvesters Ltd

CASE STUDY

HEALTHCARE

"The healthcare sector is going through a period of rapid change with the revolution in informatics being a major factor. There will be an increasing emphasis on big data sets, not only at policy planning level, but also in developing individualised care programmes.

"It is easy to underestimate the pace at which advancements are taking place: we can already map the human genome and the cost of this is tumbling. Combining this knowledge with data analysis about lifestyle and environment will enable us to identify the determinants of ill health for individuals, tailoring treatment or preventative action accordingly.

"But it will be some time before we can leverage big data to its full potential. The health service is the last major service profession to be digitised. Building efficient interoperable IT systems for such a complex organisation is a major challenge. We also have to tread carefully on issues such as data security and privacy if big data analysis is to gain acceptance from the general public.

"As with other sectors, the boundaries between the physical sciences and other disciplines are becoming blurred. For example, stem cell research requires sophisticated engineering skills as well as biology. Social sciences are increasingly being used in medicine to track and analyse behaviour patterns.

"Job roles within healthcare, from technologist level upwards, will require a much better understanding of mathematics and IT. Current IT teaching in schools is too basic and keyboard-based. The sector is already experiencing a shortage of people with bioinformatics competencies, and we expect a sharp increase in demand for these types of skills in the future."

Prof Sir John Tooke, Head of Medical School, UCL; Academic Director, UCL Partners

EDF ENERGY

With a UK workforce of around 15,600 people, nearly 40% of which have a STEM background, EDF Energy's skills requirement spans a multitude of activities, from maintaining a fleet of eight nuclear power stations, to the nuclear new build programme, starting at Hinkley point C in Somerset.

Ongoing and future challenges include managing the upgrade of IT in aging power stations, as well as a complex nuclear decommissioning programme. Engineers that have digital skills embedded into their design and commissioning competencies will increasingly be in demand as the company embarks on its nuclear new build programme. On the retail side of the business, EDF Energy is increasingly seeking IT innovators that can enhance web-based customer related programmes.

The company has a nationwide network of internal training facilities spread across its locations, and is also constructing a training campus close to Hinkley power station in Somerset. Around 70% of EDF Energy's internal training is related to nuclear activities, an essential part of which is instilling a rigorous approach to safety. Employees, whether qualified to post doctorate or apprenticeship level, will often train for six years with EDF Energy before they are considered ready to work in the nuclear environment.

"We have no problem recruiting electrical, mechanical and process engineers, but find that they are often lacking in project management and design management skills. We often have to work quite hard to develop team working and leadership competencies in our employees. We need a pipeline of people with the right competencies who can come through to industry faster.

"In my experience, some of the best engineers in our industry have not come from a nuclear background. They have mechanical and electrical training from different industries, have broad experience, and know how to think on their feet. When they come to EDF Energy we then give them the specific skills and capabilities to work in the nuclear culture. It's really important that we don't get tunnel vision when devising educational courses. Having a wide variety of skills can often enhance the quality and capabilities of the engineer."

EMPOWERING TECHNICIANS

"Companies can pump millions into R&D but it's often the technicians that can innovate and make the difference.

"EDF Energy technicians have enhanced the performance of fuelling machines at our nuclear power plants, redesigning the process, modifying the plant and optimising efficiency.

"These are highly complex machines that can weigh up to 100 tonnes and are worth hundreds of millions of pounds, removing the cores that contain radioactive fuel up to 5 to 6 to 7 m long. These have to be carefully extracted and replaced.

"The technicians understand the fuelling machines better than any of us. We also have numerous examples of how technicians have helped us to protect and improve our safety boundaries in the nuclear industry.

"I believe industry doesn't do enough to encourage technicians and technologists to feel empowered to innovate. This is an untapped area."

David Drury, EDF Energy Director of Learning Development and Chancellor of EDF Energy Campus

CASE STUDY

ARLA FOODS

"New ways of working, new environments, new global challenges, changes in lifestyle and eating habits coupled with advancements in automation and robotics are bringing sweeping changes to the food production industry.

"Historically, the food industry has recruited operatives and technicians from a pool of non-specialist candidates from the local community. The sector has often has to rely on qualified people from overseas to supply deeper food technical skills. This situation cannot continue and we must professionalise the industry with well qualified technicians on a career path within a well-managed talent pipeline.

"For example, our outbound warehouse where we store processed milk prior to despatch has numerous advanced robots. The robots have either replaced or are making life easier for people who, historically, had to work in unfavourable conditions, coping with the cold environment and walking many miles a day. The robots are also reducing health and safety risks, such as the danger workers previously faced of trapping fingers in milk despatch cages.

"These robots require new skills to keep them operating efficiently. The associated warehouse management system is complex and needs employees with the right kind of mind-set to understand and get the best out of these sophisticated systems. They need to take an intuitive approach to how the robot thinks, works or has been programmed. We need to train these skills and to keep them current and up to date.

"Local schools and colleges have to understand what our recruitment standards are and what our training needs will be in the future. The assumption that we employ unqualified people no longer has a place in Arla's culture of learning. We will help employees develop and grow in this new age of innovation, but they must bring with them the personal behaviours that will spur them on to achieve.

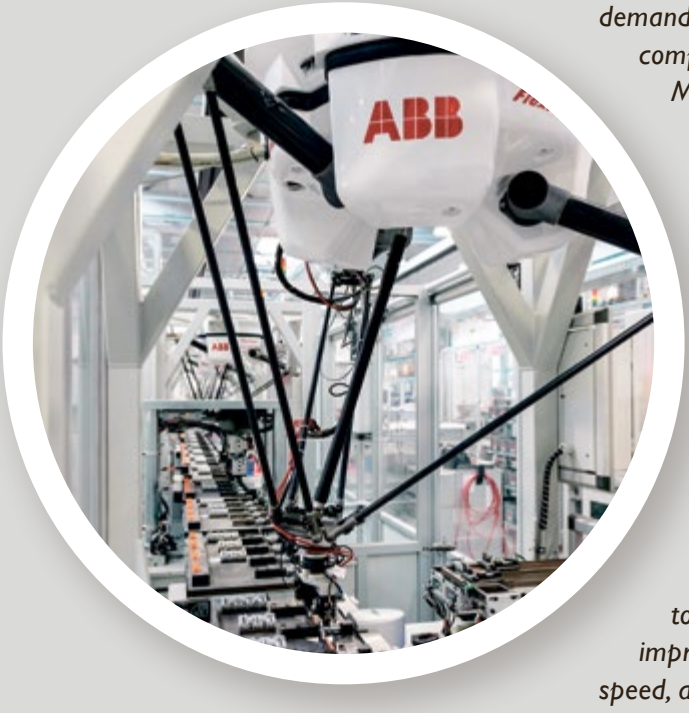
"The UK education system has largely ignored the food industry, so major food and drink employers have come together to create a framework for technical skills. This has notably been in the dairy sector but will expand across the board with new initiatives such as Trailblazers and employer ownership pilots. With the direct help of the National Skills Academy for Food and Drink and our trusted training partners we have been in the driving seat for changing how we train our people in deep technical skills, on and off site, including technology and engineering at Levels 2, 3, 4, 5,6 and 7.[8] Arla is also helping to lead on a new Masters in food engineering at Sheffield Hallam University."

Chris Edwards, Senior HR Consultant in Learning & Development

[8] See Ofqual's definitions of learning levels in the appendix page 56

ABB ROBOTICS

More than 80 people work for ABB's robotics business in the UK, providing customer support services for the company's robotic products.



"These are exciting times for robotic automation. In 2012, demand for industrial robots in the UK increased by 82%, compared with a 68% increase the year before.[9] Much of this has been led by the rapidly expanding automotive sector, with robots playing a major role in helping companies to scale up their operations and expand their product ranges.

"The challenge is to translate this success into other market sectors and include uptake among SMEs.

"Many robot manufacturers, including ABB, are now developing a new generation of robots that are cheaper and easier to buy, maintain and use. Ongoing developments include simplified programming tools, remote monitoring tools for maintenance and diagnostics work and improvements in hardware which increase the handling, speed, accuracy and vision, as well as greater overall intelligence of robots.

"Robots present new opportunities for improving and enhancing the skills of the workforce. As robots begin to appear in larger numbers on UK factory floors, there will be a corresponding increase in demand for staff that can work with all aspects of this discipline, from specialist programming through to operation and maintenance. However, a recent ABB study reveals that the lack of available skilled workers able to work in this field is a key obstacle to the uptake of robotic automation in the UK.

"Having technically advanced engineers will be essential for companies to get the most out of robots throughout their operational life. So robot manufacturers need to play a central role in ensuring the ready availability of training at all levels. This involvement should not just extend to the immediate workplace, but also to the grassroots level in schools and colleges, exposing young people to the possibilities of this rapidly developing field."

Mike Wilson, Sales and Marketing Manager - General Industry, ABB Robotics

[9] Figures supplied by the British Automation & Robot Association

CASE STUDY

JAGUAR LAND ROVER

"In the future there will be a growing demand for employees who can work with virtual reality software to create prototypes. As well as competencies in 3D modelling, prototyping work requires a strong grounding in maths and physics along with data modelling and analytical skills.

"Design engineering courses do not place enough emphasis on computer modelling. Students don't understand how it works, and often lack the basic knowledge that underpins it."

Jo Lopes, Head of Technical Excellence, Jaguar Land Rover

CASE STUDY

CALISTA

Renewable energy products specialist Calista Group was established in 2014 and currently employs eight people.

Calista is developing a range of innovative products, including a cylinder suitable for carbon dioxide air source heat pumps, believed to be the first of its kind in the UK.

As most people working in renewable installation are either fully qualified electricians or gas fitters, Calista founder Paul Brown is working with Petroc College in Devon to develop an NVQ-endorsed renewables apprenticeship course which combines elements of both disciplines.

"As well as technical skills, colleges should also teach students the basics of running a business. The students that I meet don't know how to tender or how to work out profit and income. They have no understanding of how companies work.

"Over the past two decades that I've worked in construction, I've met many people who would like to start their own business, but don't know how to. And small business owners often lack the skills to scale up to the next level.

"SMEs face different challenges in our search for skills. Larger organisations can easily go to colleges and know how to attract funding for apprenticeships. But SMEs don't understand the system and cash flow is also a problem.

"SMEs can also struggle to provide adequate experience for apprentices if the business activities don't provide a wide enough variety of tasks to carry out. One way of addressing this issue could be sharing apprentices between different companies. In this way they could get fully rounded training experience over their apprenticeship period."

Paul Brown, Managing Director, Calista Group

CASE STUDY

HOLITION

Venture start-up Holition explores and expands the role that technological innovation can play in fashion and retail, helping luxury brands find innovative ways of communicating with consumers.

Combining the expertise of luxury marketers, retail specialists and pioneers of emerging digital technology, Holition uses augmented reality, holographic, projection and touch solutions to create memorable consumer experiences online, in store and through mobile.

Holition's global network of clients includes Richemont, LVMH, Swatch and Kering Groups. Recent projects include an augmented reality campaign for a leading lipstick brand and the world's first holographic fashion show in Shanghai. Installations have taken place at premium retail stores including Selfridges and Harrods in London, Isetan in Tokyo and Bloomingdales in New York.

Despite the highly experimental and innovative nature of Holition's work, the company describes itself as 'technology agnostic':

"We put strategy and creativity first. Only then do we consider the appropriate technology to deliver the idea. For each project we bring together a very diverse team of experts. For example, we are currently experimenting with ways of capturing data from satellite weather forecasts and transmitting the signals to items of clothing, changing their colour and appearance in real time. This kind of work requires input from 3D modellers, 2D designers, strategists, data architects, visual artists and mathematicians. We also need people who can work with mobile technology and object tracking.

"It's very important that all our employees have a mutual understanding of other disciplines, when undertaking this kind of collaborative work."

Jonathan Chippindale, CEO Holition

CASE STUDY

SUNSEEKER INTERNATIONAL

Luxury motor yacht designer and manufacturer Sunseeker is the largest private employer in Poole, Dorset with a workforce of approximately 2,200 people.

"We have a fluctuating need for people who can work with composites and regularly experience shortages of skilled composite technicians who can work with both open and closed GRP mouldings at our busiest times of the year.

"Most local colleges across the UK do not offer composites courses and there seems to be a lack of understanding about the subject generally within schools and further education providers. We find it easier, cheaper and faster to carry out un-accredited training internally.

"It's also problematic accessing training in hydraulics. The nearest quality hydraulics training provider is based in Worksop, Nottinghamshire – The National Fluid Power Centre. We continue to work closely with our training provider, Bournemouth and Poole College, to address these shortfalls."

Alex Bowman, Training Manager, Sunseeker International

CASE STUDY

WORCESTER BOSCH

The Government's drive to reduce carbon dioxide emissions by at least 80% (from the 1990 baseline) by 2050, has had a powerful impact on the heating appliance market.

Like many companies, Worcester Bosch is increasingly switching its research and development focus away from purely gas-fired boilers to other low carbon technologies.

In the short term, the development focus is on hybrid products: an electric heat pump for background heat combined with an integrated gas boiler for rapid heat. In the medium term, gas absorption heat pumps may well be introduced into the domestic market as the next phase of efficiency development.

Until recently, heating systems were reasonably generic and relatively straightforward to install. But as they become more sophisticated, new products and technologies will become increasingly complex to install and maintain.

Heating engineers of the future will need a working knowledge of several STEM-based subject areas including: how to carry out more precise heat loss calculations, how the orientation of a building affects thermal performance; how to carry out whole house energy assessments. In certain circumstances they may also need to understand geology (for installing geothermal heat pumps) and to develop more advanced IT skills.

Those working on commercial and large new build developments should develop expertise on how building design and new materials impact on thermal efficiency.

"As a company, our focus is on addressing the shortage of competent engineers. We are dramatically increasing apprenticeships and are working with our LEP to identify employment and skills issues in discussion with higher and further education institutes, training providers and schools."

Carl Arntzen, Managing Director, Worcester, Bosch Group

WHAT CAN WE LEARN FROM THE CASE STUDIES?

Industry feedback, across many sectors, suggests that further and higher educational institutions are too focussed on immediate and short term skills requirements.

Leading companies are devoting considerable time and resources to forecasting future technology trends. If this knowledge was shared more effectively with colleges and universities, it could have a transformational effect on courses, addressing skills requirements at both a regional and national level.

STEM-sector companies specify degrees (or similar) as a minimum entry requirement. Yet many graduates are ill-equipped for the workplace and undergo extensive retraining. **There is a misalignment of what industry expects and what education provides.**

Given the poor alignment of many higher education courses with industry, the assumption that only graduates can be effective in certain job roles may be a costly misjudgement, both for industry and for the students.

Whilst university courses (correctly aligned with industry trends) will be essential for developing technologists of the future, we should not ignore the valuable contribution that further educational institutions could play: bringing forward industry-ready workers in a much shorter space of time.

Every level of STEM education has a vital role to play in helping students understand how they can apply their knowledge - across a variety of sectors - in the real world. Colleges and universities need to develop flexible workers with a more innovative mindset. Industry newcomers of the future need to:

- Be flexible: adapting to changing technology
- Have a broad understanding of how their STEM skills can be applied across a range of sectors and to a variety of markets
- Be empowered to innovate and invent
- Understand that they may have a variety of different job roles and work in several different industries over their career
- Have an entrepreneurial mindset, either for working within large organisations or launching their own businesses
- Combine STEM-skills with other highly valuable competencies, especially project management skills, collaboration and interdisciplinary team working, data management and data modelling
- Have a knowledge of legislation
- Have financial acumen, fundraising and business development skills
- Develop an awareness of presentation, marketing and communications
- Have an understanding of how to build relationships with customers, clients and stakeholders
- Develop the ability to think laterally and spot new product opportunities

In summary: collaboration between industry and education is essential

Technologists of the future need to have the skills and expertise to traverse multiple industrial sectors.

They need to have a combination of **transferable technical, professional and personal skills, abilities and attributes.**

Learning should be designed to enable **practical and experiential engagement** across various disciplines, developing a strong, creative, problem-solving capability in students.

Structures need to be put into place to create **a more conducive environment** for **collaboration and co-creation** between industry and education.

Companies must work closer with educational institutions, **sharing knowledge** of technology trends and future skills requirements, **advising** on the types of training and learning that would be **most relevant and practical** to their needs.

In addition:

- Colleges need to understand the **complexity of the workforce** in most STEM companies as well as the multi-faceted nature of specific job roles
- More attention should be paid to **the entire supply chain**, both by educationalists and major manufacturers **Engagement** with **small and medium sized companies** should be encouraged
- A long term and sustained exchange between academic and industrial organisations should be widely encouraged: access schemes for lecturers into industry are currently too sporadic
- Industry staff should also work more in colleges
- There needs to be a change to the funding mechanism: funding is supply-side initiated and too focused on short term industry needs. A longer term solution that takes a sustainable view of industrial trends is required

ECONOMIC CONTEXT AND IMPLICATIONS[10]

Over the long term, increased productivity is the key determinant of economic growth and, together with higher employment, is the principal means of raising living standards.

STEM-based industries are critical for driving improvements in productivity.

There are two ways of increasing gross value added (GVA) productivity:

1. To have a higher level of employment or more working hours so that the total labour input to the economy increases
2. To increase the amount of output that each person produces, (i.e. the capability of individuals and the competitiveness of firms)

Given the potential limitation on increasing the UK's labour force without increasing the population, **boosting the UK's productivity is generally accepted as the primary route to improving our future standard of living in the long term.**

ECONOMIC CONTEXT

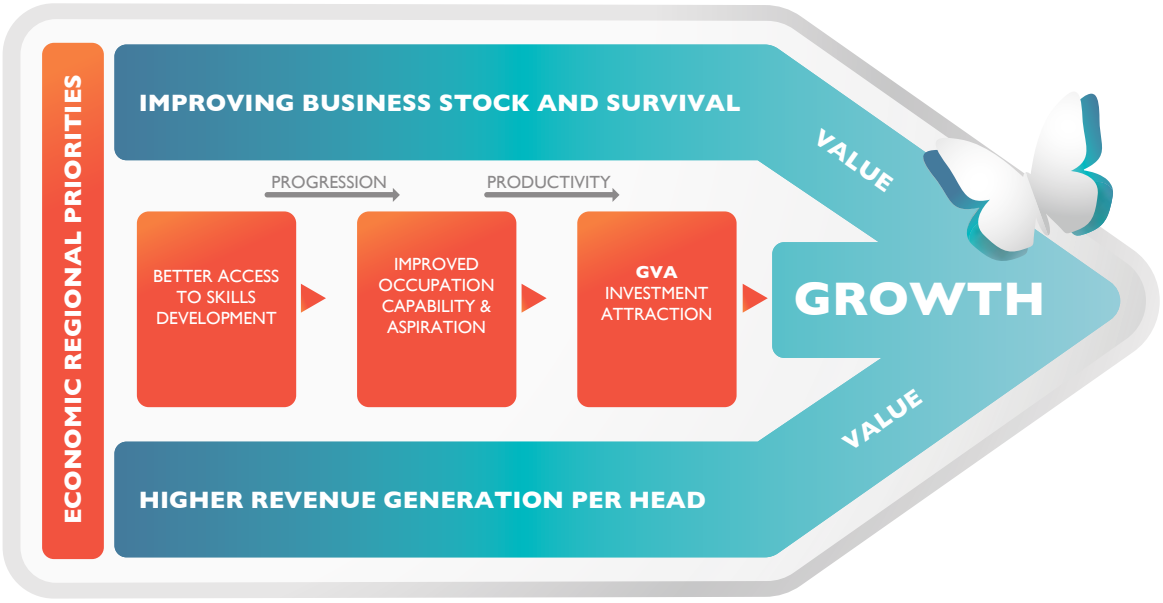
"...UK output per hour worked still lags behind that of our international trading partners in the US, Germany and France.

This gap is apparent across most sectors of our economy, but especially in manufacturing. Based on these measures the average UK worker has to work 10 hours to produce the same output that a worker in the US could produce in eight. How much more productive would we be in the UK if we enabled UK workers – through investments in skills, infrastructure, capital equipment and R&D – to be as productive per hour as our leading competitors? This is not just about working harder, but about being more productive with the time we put in."

No Stone Unturned, In Pursuit of Growth
Lord Heseltine, October 2012

In order to increase productivity of individuals or companies, it is necessary to increase the skill level of both the existing workforce and industry newcomers.

[10] A more detailed economics explanation can be found in the appendix page 57



This is particularly true in scientific, engineering and technical occupations where advances in technology can quickly render current skills redundant.

In order to improve the occupational profile, education providers, learners and employers have to raise their aspirations: **The qualification and learning process has to be reconfigured.**

NEF has carried out a three-year review of further education colleges, assessing how technical, professional and personal skills were measured and developed. STEM provision was found to be inadequate in virtually every case. In the worst examples, 80% of a curriculum was 'misaligned' (it did not match industry trends)

Urgent action is needed

This situation cannot be allowed to continue. Maintaining the status-quo can only result in low level training or a short lived and localised benefit for an employer or group of businesses.

Even worse, it could contribute to the death of micro and small enterprises in a region, through neglected opportunities.

There is an urgent need to achieve better alignment between the following key players:

- Businesses (markets)
- Skills producers (higher and further education providers, private providers, company academies)
- Government (enablement policy or interventions to address market failure)

In Business – the largest area for employment growth is in "replacement demand": (replacing people who have left the industry through retirement). Growth in new jobs is mostly limited.

But, even when replacing people, this is no longer a like for like exchange –the skill level entry criteria for newcomers is constantly being tweaked upwards, in line with evolving technology.

In Education and Training – The content and structure of significant courses is inflexible, outdated and out of sync with industry's needs.

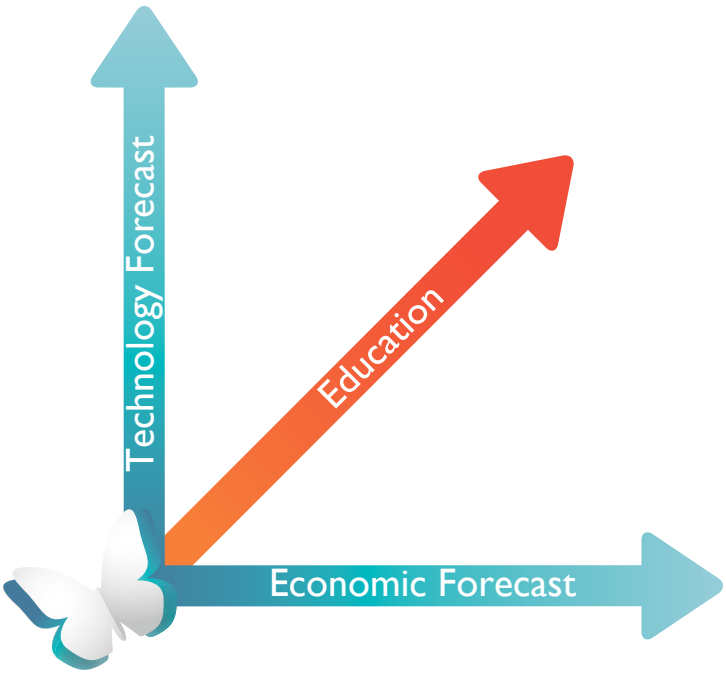
Many of the staff teaching the STEM disciplines are working from outdated knowledge, using methodologies that they learned themselves decades ago. Many colleges also focus on very low level training, despite the growing job opportunities requiring more sophisticated skills.

Colleges continue to teach traditional trades such as carpentry, which will be less in demand in the future. At the same time, engineering courses are failing to embrace new technologies such as building information modelling, which will become compulsory on all Government projects from 2016.

In Government – A step change in policy thinking is required. Government and Local Enterprise Partnerships (LEPs) need to take a fresh approach to developing cost-effective skills provision for the economy.

Forecasting in context

NEF makes two cautionary points when it comes to interpreting economic forecasts needed to inform the development of new STEM programmes:



Techno-Economic Assessment of STEM Skills Needs

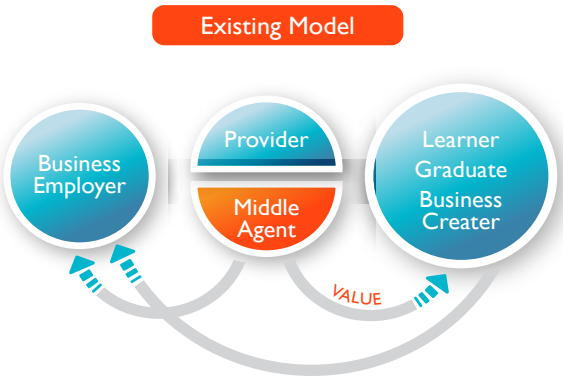
1 Many of the conventional SIC (Standard Industry Classification) codes, which were developed in 1948, do not align directly with the new and emerging technology sectors. For example, the digital economy is substantially larger than conventional estimates suggest, according to the NIESR, the National Institute of Economic and Social Research. NIESR's conservative estimate suggests that there are almost 270,000 active companies in the UK digital economy, whereas the Government's estimate was 167,000 companies in 2012[11]

2 Economic data is not sufficient to be used on its own to identify and interpret STEM skills gaps. Such data will need to be interpreted within the context of technology change and projections. In addition, colleges and universities tend to seek input from training managers whose focus is primarily on immediate training requirements, and often render limited information on the skills needs of business, particularly in STEM areas. Information from training managers, whilst important, will need to be blended with input from other internal company sources to provide a richness of intelligence. This includes forecasts on technological developments and the direction of travel of the business

[11] ***Mapping the UK Digital Economy*** report, 2013, National Institute of Economic and Social Research & Growth Intelligence

THE TRADITIONAL MODEL

The learning engagement model: as it is now



The traditional educational model exists between three parties:

- The business (employer)
- The student who, as well as becoming an employee, could also start a business
- The education provider, acting as a "trusted middle agent"

How the education provider adds value

The education provider creates value for the employer in several ways by:

- Assessing and accrediting the learning. The provider may engage with the awarding bodies to administer qualification delivery
- Engaging with employers to identify and analyse their specific training needs
- Delivering an educational strategy to address skills deficiencies

On the surface, this system appears to meet the needs, both of the employer and the student. But when looked at more closely, deep rooted problems emerge. The value gained from the overall transaction between education provider and student is limited, particularly when taking the employer's long term strategy into account.

This is because the provider's offer is too embedded within traditional disciplines and training silos:

- The cross-curricula nature of learning is still very limited
- Qualifications and means of measuring capability are restrictive and outdated

The perceived value of STEM-based education has been steadily eroded over the past few years. Trust is breaking down between parties: companies doubt that they can recruit people with the right skills. Students worry whether their overall training and experience will make them employable.

Employer engagement: the current situation

Employers have traditionally engaged with industry newcomers and employees with a range of activities, initiatives and approaches. These include:

- Responsive teaching and learning developments that raise the skill level and develop people already in work
- Working with colleges and universities to enhance the employability of students in further and higher education

There are many benefits to companies or sectors seeking closer engagement with students: the student is able to put theoretical knowledge into practice, gaining relevant experience and useful exposure to current industrial practices and technologies.

But there are also some disadvantages: workplace learning programmes can have a very narrow focus, confined within a traditional silo or configured to company-specific parameters. As well as confining the field of learning, the student's intellectual development is limited to the perspective of 'here and now' immediate requirements.

Employer academies: a growing trend

Major employers are increasingly meeting their specific skills requirements by creating their own academies, campuses and training centres.

The rapid emergence of these new educational establishments, particularly in energy, automotive and advanced manufacturing sectors (EDF Energy Campus, The Honda Institute, and JCB Academy) reflects a frustration with the old ways of learning: companies are striving to control the quality of the educational process, configuring, developing and delivering training that supports their strategic goals.

It is interesting to note that many of these initiatives are being developed in close association with colleges and universities. As the number of company academies and training centres increases, there is likely to be a strong demand for institutions that can collaborate, co-create, validate and support the delivery of industry-targeted programmes.

The fast-expanding trend in companies becoming accredited training centres, with the ability to issue certificates and carry out qualification assessments, is likely to increase over the coming decade.

Employer academies undoubtedly offer a vibrant and more relevant alternative to many traditionally based courses and could make a valuable contribution to STEM education in the future. However, there is a risk that they could focus too much on the needs of one particularly company or sector, placing a lower emphasis on teaching transferrable skills. This could lead to a less flexible workforce.

Sector specialist colleges

There are numerous examples of sector specialist colleges springing up in industries ranging from food to rail to nuclear. Whilst these colleges are often very close to industry and play a valuable role in serving the immediate and medium term needs of particular sectors, they do not encourage **cross sector collaboration** that is necessary to **foster innovation**. There is a strategic need to build a multidisciplinary and flexible workforce that can operate in different sectors, responding to different trends and market opportunities.

Apprenticeships

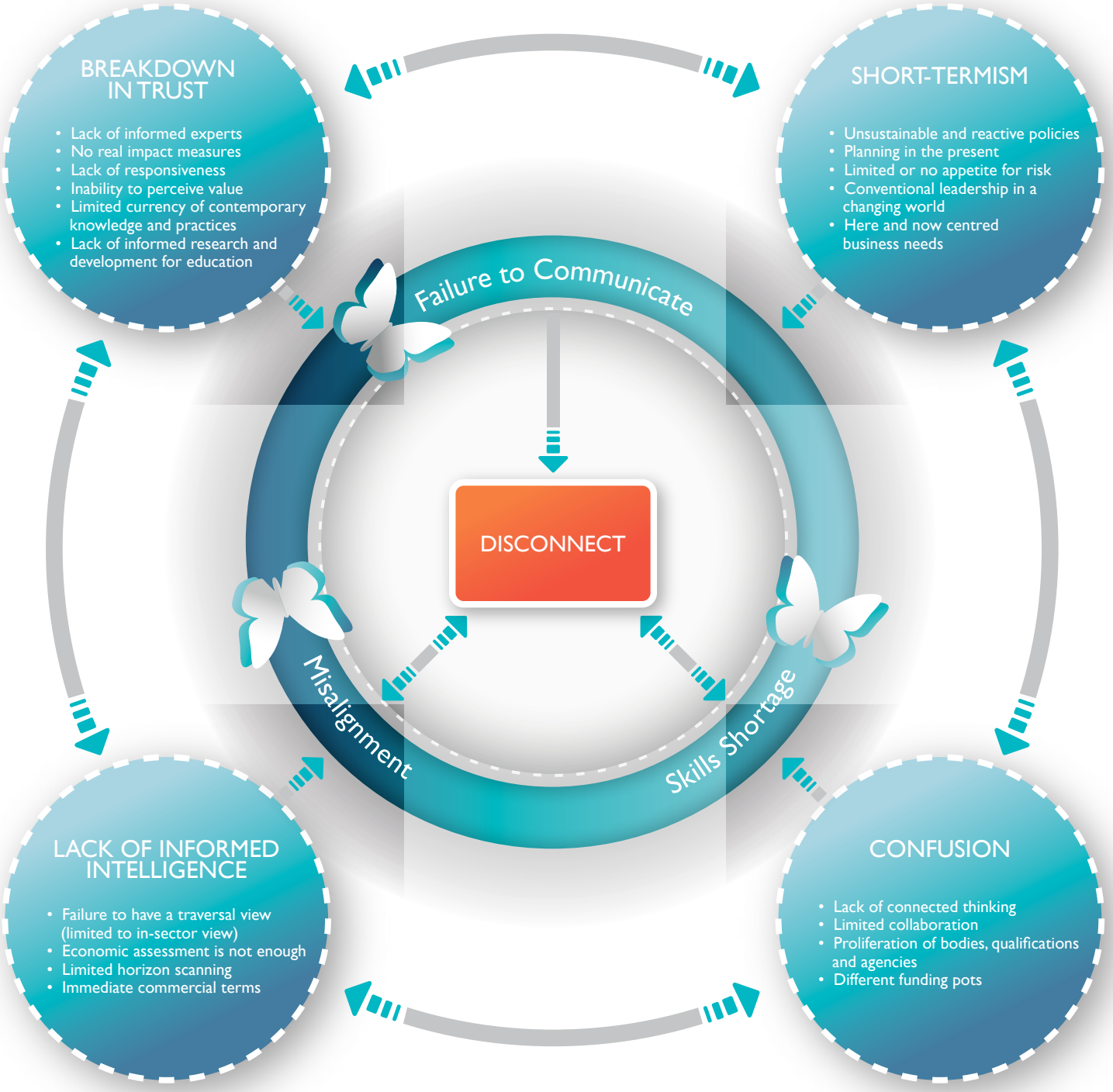
There has been much discussion in recent years about the value of apprenticeships. These programmes can offer a useful route to industry for school and college leavers. However, the current system has some drawbacks:

- Apprenticeships are inconsistently measured, and there is no recognisable standard between companies.
- The value for the learner varies considerably depending on college, sector and placement
- Apprenticeships are often inflexible and take a very long time to complete
- They are usually tied to a particular sector and limited in their outlook, unable to respond to future changes in technology
- SMEs suffering a skills shortage can be reluctant to take on apprentices due to barriers of cost, administration and resources. Those that do participate are not always able to give the apprentice the full range of practical experience that they require
- Apprentices can suddenly lose their placements – and may be forced out of the educational system altogether - if companies downsize or go into receivership

THE CHANGING FACE OF STEM EDUCATION

Today, a number of factors are reshaping both the demand for training and approaches to learning. These include:

- Funding constraints
- The need of businesses to quickly respond and adjust their workforce to variable trading conditions
- The ubiquitous nature of digital learning
- New working patterns (e.g. teleworkers, project centric, portfolio careers)
- Changing behaviours and trends in the educational landscape such as:
  - Colleges and universities driven by learner demand, learners as customers
  - Learn-and-earn, and online/distance learning opportunities which offer new models of delivery and access at the point of need
  - Employers creating their own dedicated training facilities to address business needs



Preparing for a new approach to STEM in further education

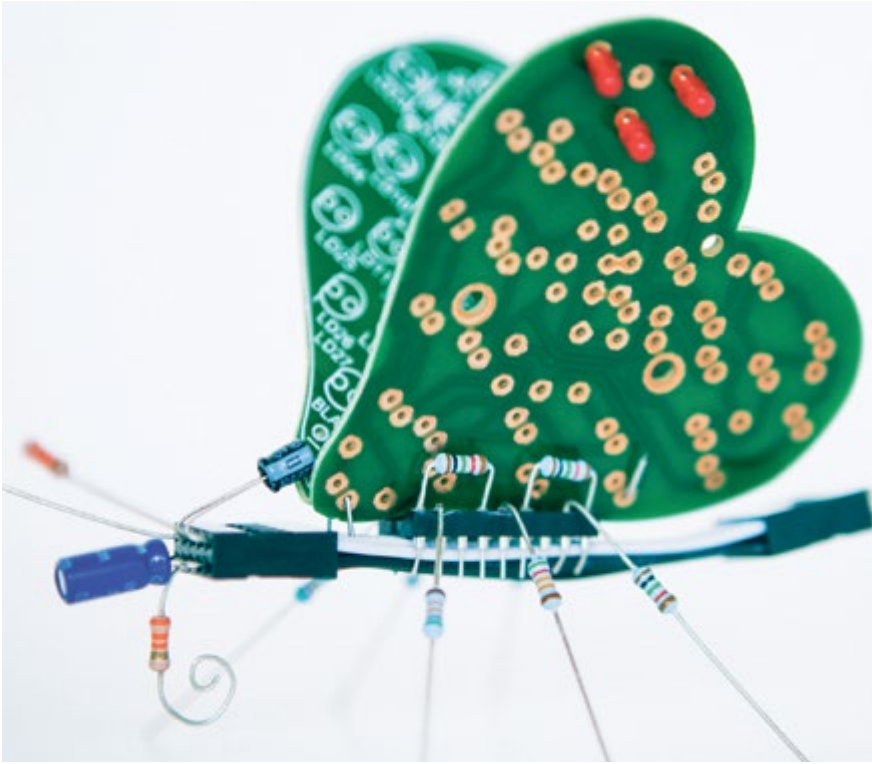
Current education strategy can be traced back to a model first developed in the 18th century to educate the masses to a common point of literacy and numeracy. Reinforced by early 20th century concepts of mass production and efficiency, the model commonly manifests itself as:

- Large numbers of students on common pathways and similar levels of attainment
- The teacher as a leader of learning, delivering knowledge
- The classroom as the physical space for formal learning
- Subject matter compartmentalised into separate disciplines with little overlap

The following assumptions are also commonly made in the current system:

- Attainment is best assessed by an independent body and that assessment is most usefully carried out as a synoptic experience, focusing on one subject and carried out at a single moment in time for the entire student group
- All other learning is subsidiary to that which takes place within schools, colleges and universities

It is not new to state that this model is ineffective: educational experts have long advocated enquiry-based learning in flexible learning spaces. Here, learners lead their own learning process and teachers act as facilitators, guiding rather than directing.[12]



Current teacher training, however, is still based on the traditional model. This is certainly not appropriate to vocational training with industry relevance, never mind the education of our young.

Ever since it was founded in 2004, NEF has been working to change this situation by offering unique programmes for STEM lecturers in further education colleges. NEF's Industrial Fellowship Scheme and masterclasses support continuing professional development, informing on relevant industry trends and providing updates on technological advancement.

There have recently been discussions on how to bring people from industry into teaching through the Train to Teach government initiative. Whilst NEF advocates this approach, there has so far been little discussion of how to help industry experts make an effective transition to STEM education.

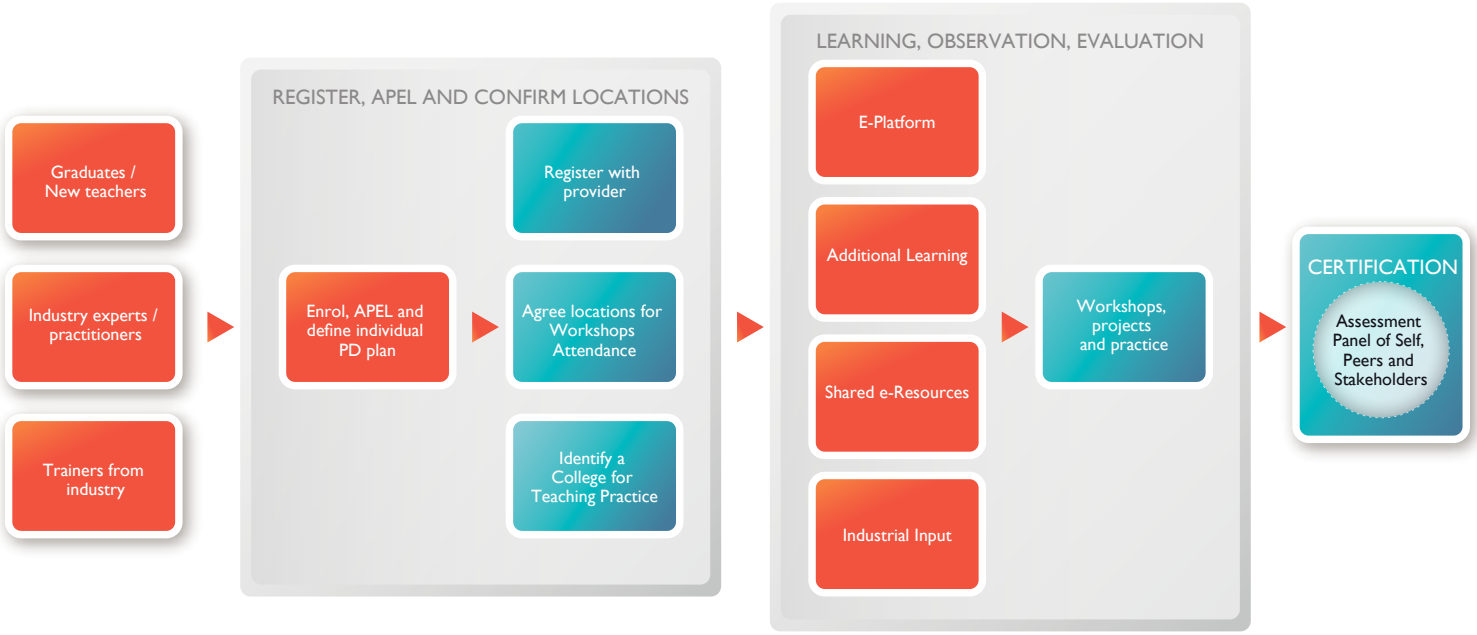
In fact, whichever path new STEM teachers have followed, whether they have come up from industry or are fresh from academia, there is very little research on how best to prepare them for the workshop or classroom.

This paper proposes a model that creates an efficient, effective, flexible and sustainable initial teacher education (ITE) in STEM for further education institutions:

[12] C5 Effective Environments for Enquiry-Based Learning, Karen O'Rourke and Norman Powell, The Centre for Excellence in Enquiry-Based Learning (CEEBL), The University of Manchester, UK

ITE model in STEM further education

This model can be applied to trainee lecturers entering STEM sectors via different routes to become new facilitators of learning. Such a teacher development programme would need to combine the dual professionalism of STEM practice and knowledge with truly effective teaching and learning practice. It would acknowledge prior learning and experience.



The model would need to embed new practices in teaching that are reflective of interaction in the world of work, such as new digital technologies, mentoring, reflective learning, workshop-based learning, projects and real assessment practices. NEF proposes a framework that should include areas such as research and planning; engagement; design and delivery; impact; innovation and standards.

For this model to work effectively, attention should also be given to the following:

- **Leadership** – management and heads of education providers also need to understand and commit to a fundamental shift in approach to delivery of education
- **Physical and collaborative structures** – education providers should not be competitors, but need to work collaboratively, in new spaces for education

A NEW ROLE: THE TECHNOLOGIST

As this report illustrates, we are living through an age of rapid change, and the pace of change is accelerating, driven by advancements in technology.

The boundary around traditional scientific disciplines is dissolving: many of the most exciting developments of research, product development and manufacturing are fuelled by the convergence of disciplines.

Cross fertilisation between disciplines, such as in the field of biotechnology, will give rise to new areas of research and innovation in the near future that are unimaginable today.

PROVOCATIONS

- **Economic growth requires more sophisticated technologists for the future – current educational templates are redundant**
- **The key to traversing science, engineering and technology markets is having an 'interoperable' workforce – a product of open architecture learning**
- **Education is not linear – the student is the teacher and could also be the business leader**

This has profound implications for our workforce, both now and in the longer term. Whether engaging with robotics, aerospace, city design or cloud computing, companies are increasingly seeking technologists that can transcend narrow scientific silos.

Technologists of the future will need to

- Become more adaptive learners able to respond to technological change
- Be able to operate in different sectors and contexts with confidence, in response to demand
- Have higher functioning capabilities in:
  - Digital
  - Logic
  - Design
  - Interaction
- Have a good level of dexterity and sensory skills
- Have an entrepreneurial mindset, able to imagine or invent new applications for products or technology in different sectors

It has been widely reported that many STEM-based sectors are experiencing a serious skills gap. This admittedly worrying situation should be viewed in a wider context.

Merely training a worker to do a single job, and to work only with today's technology, is a myopic and short term solution. We need our workforce to be agile and ready to take up new challenges. Our students need to develop skills and mindsets that will enable them to work in an environment of rapid change.

At present, there is little incentive for training providers to adapt their offer to meet what the economy needs. The majority of funding comes from the Skills Funding Agency, not the employer or learner. In 2010/11, for example, total FE college income was more than £7.5 billion, of which only 2% was fee income from employers. What this means is that providers are able to pick and choose what training to deliver, and employers are often unaware of the quality, relevance or benefit of the training being provided[13]

Lord Heseltine

[13] *No Stone Unturned: In Pursuit of Growth*, Lord Heseltine, October 2012

A TRANSFORMATIONAL APPROACH

Our education and training system is not delivering future technologists. The current system works as if education were a linear process: spitting out a 'final product' at the end of 18 or 21 years that has been shaped by the occupations and technologies of yesterday. We need to take a more imaginative approach, reconfiguring our educational institutions and courses to make them more flexible and relevant for a future that cannot be predicted.

STEM-based education has to undergo a transformation as radical as that ongoing in industry. This poses an enormous challenge for education providers, industry and the Government. But ignoring this issue will stifle innovation and could damage the UK's long term economic prosperity.

Inventing the Future has consulted with a wide range of science, engineering and technology companies of different sizes, assessing how much **value** current learning systems offer both employer and student, and the extent to which the value is **trusted** by both parties.

This chapter visualises what sort of learning environments would be most conducive to driving innovation and growth as well as **building value** for the student.

Two clearly defined STEM paths

Educational provision is likely to be developed along two clearly defined paths. A coordinated regional approach will lead to the development of institutions that complement each other and raise standards of training for all levels of industry entry. These paths are:

- **Community education centres**, whose purpose is to drive social development inclusion and raise the educational attainment level of learners within a region. Low level health and social care provision could also be included in this path. Capital equipment, laboratories and resources will attract a much lower scale of investment. Companies' corporate social responsibility remit could play a key role in supporting such centres
- **Regional polytechnics with vertically integrated educational provision:** these 'new style' polytechnics will focus on developing learners who will contribute to building economic growth and productivity within a particular region. They could accept learners from the age of 14, subsuming the existing university technical colleges' structure. Capital infrastructure and technical resources will attract a higher scale of investment

The proposed regional polytechnics could develop out of existing institutions, such as new universities, that have a strong industrial focus. They could also grow out of further educational colleges.

A variety of local organisations, such as schools and colleges could actively participate with the regional polytechnic, taking or running its courses as 'concessions'. Companies could also take responsibility for individual course modules or even departments.

Within this model, there should be more exchange of personnel between industry and education: academic staff could be co-located or seconded into companies to help develop and deliver new programmes. Industry experts could move into colleges and universities, either on a part time or temporary basis.

Governance: companies could and should play an active role in these new educational formations. Areas of collaboration could include:

- Joint investment in capital projects and sharing of assets
- Engagement in applied research and development
- The formulation of curriculum and delivery strategies

Drivers for polytechnic learning

The research suggests a number of key areas on which a future regional polytechnic should focus. These include:

- **A curriculum that is not fixed, but evolves to keep pace with changing trends and technology:** Employer engagement in the learning space will be prominent: it will enable the evolution of a highly-customised learning and training system that meets current and future workforce development needs
- **Courses will be open and flexible:** catering both for students that want to follow a full curriculum, and workers who want to top up their knowledge with individual modules
- **Instead** of receiving information passively, students are engaged as **active partners** in **collaborative learning**. To achieve this shift, a more flexible approach is required to the context of delivery and structure of the curriculum
- **More recognition needs to be given to the importance of cross-curricular and extra-curricular activities** as a means of encouraging students to become confident individuals capable of making a full contribution to society
- **Lecturers of the future** will assume the role of coaches rather than teachers. This includes harnessing the benefits of technological change and developing more flexible approaches to collaborative teaching and learning
- **Applied Research and learning transfer** will encourage interoperability of skills across multiple sectors: technologists will develop core competencies that enable them to move confidently from one sector to another, with a minimum of additional training investment

CASE STUDY

SOUTHAMPTON SOLENT UNIVERSITY

"As a new university, our focus is on practical knowledge and employability. We add value to our courses wherever we can, integrating learning with authentic industry experience.

"As well as catering for full-time undergraduates, we enable people to study on flexible and open courses and also run online Masters programmes whereby students don't come into the university at all.

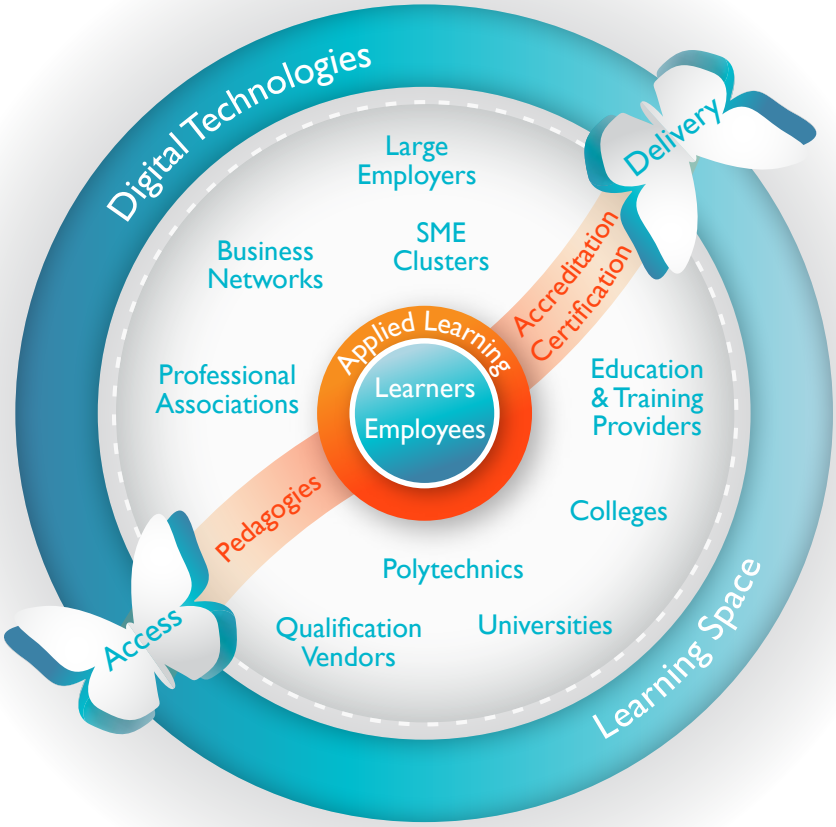
"Part time study is encouraged, both at undergraduate and post graduate degree level. For example, people already working in the acoustics sector can choose from individual acoustics modules that are most relevant to them, with the option of working towards a professional diploma or Masters if they choose to. Wherever possible, learning tasks are tailored to the specific requirements of the employer and they carry out all their learning projects at work. For me this is a platinum standard programme: the students have incredible levels of support from their supervisors both in the workplace and from Southampton Solent, and the company has confidence that the employee is picking up the necessary skills.

"Next year we are trialling an alternative to the traditional four-year sandwich degree: we're offering three-year STEM-based courses where students spend at least a quarter of their time within a company doing specific tasks. The work-based learning element could be worth 25% of the value of the degree.

"We expect this to become a more popular option for learning in the future. As the cost of studying rises, students and parents are increasingly questioning the long term value of education courses. Gaining valuable experience within companies, at a faster pace, seems a very sensible way forward."

Prof John Chudley, Dean of Maritime and Technology, Southampton Solent University

- **The regional polytechnic will act and behave as an innovation hub**, carrying out applied research that will benefit companies in the region. It could act as a magnet for strategic investment, enabling technical capability to be clustered in areas of economic growth
- The polytechnic will **innovate and collaborate with industry stakeholders** in an inclusive and open manner



Funding regional polytechnics

Existing funding mechanisms for education and skills development, where the Government is the majority stakeholder, are neither effective and scalable nor sustainable. Future funding of learning and skills development should be regarded as a collective responsibility.

This study suggests means by which all key stakeholders – educational institutions, Government and industry – can take ownership of the funding process for regional polytechnics.

Crowd funding

In this model, a crowd funding approach with star-ranking similar to those commercial fund raising aggregators such as Kickstarter and Indiegogo is proposed for regional polytechnics:

Under this model

- Regional economic agencies such as the Local Enterprise Partnerships (LEPs) act as enablers and providers of baseline funding. This approach obviates the need for a polytechnic to respond to multiple and often contradictory funding regimes
- The regional polytechnics, and other stakeholders such as employers, research and development organisations, charities, learned societies, associations, schools and other users can all contribute financially to - and benefit from - the funding aggregator

The role of the LEP

The LEP could act as 'quality moderator', ensuring that educational provision provided by the regional polytechnics meets the demands of employers and learners.

Working with a broad spectrum of local companies, the LEP could help identify and set out the region's greatest regional priorities for STEM education, establishing a star-rating system for various groups of disciplines. Organisations could 'bid' for the development of STEM specialisms in their region.

The LEP would also encourage collaboration and co-creation between different players, bringing new organisations into the system, thereby driving open innovation for competitive advantage.[14]

Advantages:

The proposed model will support and reinforce the following:

- **A better 'regional responsibility' mandate** that encourages inclusion and more effective participation of all key players
- **A more democratic process** smaller organisations, which do not normally have the time or resources to influence local education programmes, could become involved with the debate
- **The system would be self-calibrating** learning is co-created, almost in real-time, through a collaborative bidding and aggregated funding model that responds to changing regional requirements
- **Learning models could be fluid** evolving and improving year on year, in response to industry feedback
- **Targeted funding** influenced by industry, would be in place for the development of laboratories, research facilities and other assets
- **Subject expertise** that reflects the changing profile of businesses and occupations in a region can be proactively developed in a scalable and sustainable manner

A number of guiding principles will need to be established with respect to introducing a crowd funding model to address the balance of pros and cons in such examples as:

MULTINATIONALS PULLING OUT OF A REGION AFFECTING POLYTECHNIC FUNDING AND PROVISION	The opportunity to attract more SME participation regionally and aggregate their contribution and needs
REPUTATIONAL RISK OF THE POLYTECHNIC'S QUALITY IF IT DOESN'T PERFORM	The concessionary approach to delivery enables rapid change to reconfigure and improve quality of courses without hampering the overall operation
SHOULD THE FINANCIAL STATUS OF THE POLYTECHNIC BE FOR PROFIT, NOT FOR PROFIT OR A HYBRID?	Growth in revenue for the polytechnic means investment is not highly dependent on availability of public funds

Desired outcomes

This new system could create a **trusted dynamic** between all stakeholders. It could encourage the development of **regional clusters of expertise**. The system would be future proofed: its long term vision would be constantly adjusting, in the face of evolving technology.

How meaningful is the current system of Learning Levels?

Learning levels are primarily used as demarcation thresholds. They do not necessarily reflect a level of learning capability or determine the evolving needs of the learner.

The current system of levels, as defined by the Office of Qualifications and Examinations Regulation (Ofqual 2013)[15] in the Qualification Credit Framework (QCF), spans from entry level (functional and skills for life) to

[14] This was also highlighted in *No Stone Unturned: In Pursuit of Growth*, Lord Heseltine, October 2012
"I envisage the chambers of commerce playing an increasingly important role alongside the LEP in defining and articulating the skills needs of local businesses. I also envisage them aggregating the demand from smaller employers for particular types of training and then negotiating with FE colleges and other local providers, including companies, to ensure that the demand is met"

[15] See Appendix Table 1

level 8 (doctorates, or NVQ level 5). Level 2 is the equivalent to GCSEs, level 3 to A levels and level 5 is at the level of diplomas of higher education such as HNCs, HNDs and foundation degrees.

But there is a problem with these levels. Their original intention, to provide consistent recognition of competence, knowledge or ability, has been obscured by the more urgent function of attracting funding.

Learning levels lack consistency across different subject areas and are extremely difficult to apply across different disciplines.

To place too much emphasis on these levels risks restricting the development potential of the learner. Curricula can be too prescriptive, outdated, and learners are held back by artificial barriers:

- Decisions on how to implement learning within day-to-day activities of the job are often highly subjective
- The majority of assessment methods do not measure useful competencies or reflect the impact of new technology or new ways of working
- Evidence of the lack of standardisation in different educational benchmark levels can be demonstrated by the inconsistent quality of design and delivery of the various apprenticeship programmes

Shifting competencies upwards

The convergence of disciplines and applications will dramatically change the landscape within which technologists operate in the future.

As predicted by companies and futurologists, many technologists will no longer be operating within one academic silo: their role will require an understanding of several disciplines, and a broad portfolio of competencies.

Higher skills and competencies will be expected from STEM-based workers at every level:

For example, the educational level and competencies that we currently associate with level 3 (A level, BTEC level 3), will become a basic school leaver's requirement, tackled by 16 year olds. At the same time, 16-18 year old students will be carrying out training that is the equivalent to HND or HNC level today.

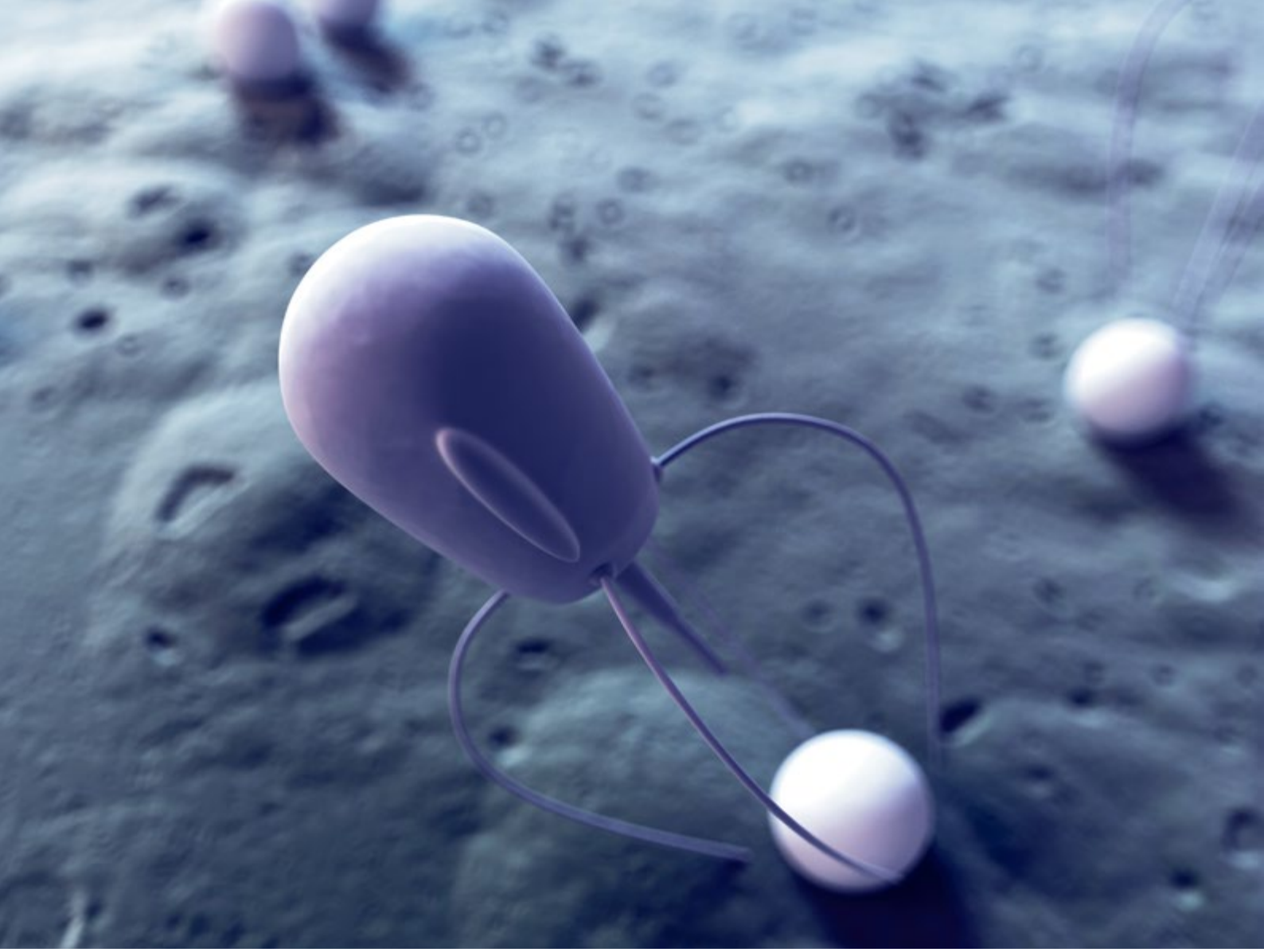
Technology-based learning will become, by necessity, more sophisticated, with learning and assessment methods tailored to the individual.

This may sound daunting to older generations, but we should not ignore the way that young people are intuitively using and adapting to new technologies today, without the help of any structured education system.

Ask any parent and they will tell you that even babies and toddlers interact with tablets and smart phones. Young people innovate online, build apps and interact with sophisticated gaming software. There is evidence that new technology is impacting on the very circuitry of neurological responses in our brains.[16] At the very least it is having a huge impact on new business models of cooperation and collaboration that are becoming natural to young learners.

But our current education system is not embracing the possibilities of technology: it is holding young people back.

[16] Communicating with the Future: How Re-engineering Intentions Will Alter the Master Code of Our Future, Thomas Frey 2012



In the future, an integral part of education will be placing learning into a broad context, whereby students understand the variety of applications to which science, engineering and technology concepts can be applied. When learners have acquired the skills to perform an identified job task, simply knowing how, and, when to apply them can promote a change in job behaviour, which is important in a dynamically changing work environment.

Determining the specific competencies to be addressed by an educational and training programme, as well as their appropriate and logical sequence, will greatly enhance the quality of STEM education.

NEF: The journey so far

NEF: The Innovation Institute has been working the companies and education providers for more than 10 years to encourage innovation in the workplace and closer collaboration between academia and industry.

The Institute's Industrial Fellowship Scheme is a professional development programme that seconds FE lecturers in STEM sciences to posts in companies. The NEF also runs masterclasses for education providers on pioneering and new technologies that are transforming the workplace.[17]

[17] These programmes are supported by the Gatsby Foundation

A TIMELINE FOR CHANGE

In June 2011: The Intelligent College

The Intelligent College, launched three years ago by NEF, builds on current best practice, setting out a route map to help colleges shift from being reactive – shaped and guided by funding, inspection and national initiatives – to become sources of innovation where emphasis is placed on individual learning. To date NEF has helped more than 70 colleges realign their strategies to reflect technological change and industry demand.

December 2012: The T-shaped Technologist

NEF published a white paper, The T-shaped technologist,[18] which sets out the required skills and competencies for senior technical employees who lead technicians and are in often in supervisory roles.

The paper establishes the experience, personal qualities and professional skills that shape the T-shaped technologist, bringing out the qualities of leadership, enterprise and a drive for innovation.

University technical colleges and companies are working with NEF to take on board the T-shaped technologist framework to professionalise technical innovation and enterprise skills in industry newcomers.

July 2014 – Inventing the Future

This new paper builds on NEF's previous recommendations and initiatives, encompassing further education and universities. Following our extensive work with industry and academia, it is clear that entirely **new regional models** are needed to create an education system that is more **agile and responsive** to changing industry trends.

A more imaginative approach is necessary to fast track the development of interoperable technologists, creating the flexible and dynamic workforce that the UK so badly needs.

THE WAY FORWARD

To meet the needs of the future, a structural transformation of our education eco-system is required. Mindsets and models must change, both in industry and academia. At present, it is usually only the largest companies with deep pockets that have the resources to influence local education provision. If we are to break the habits of the past, it will be important for companies of all sizes to start taking more responsibility for STEM education.

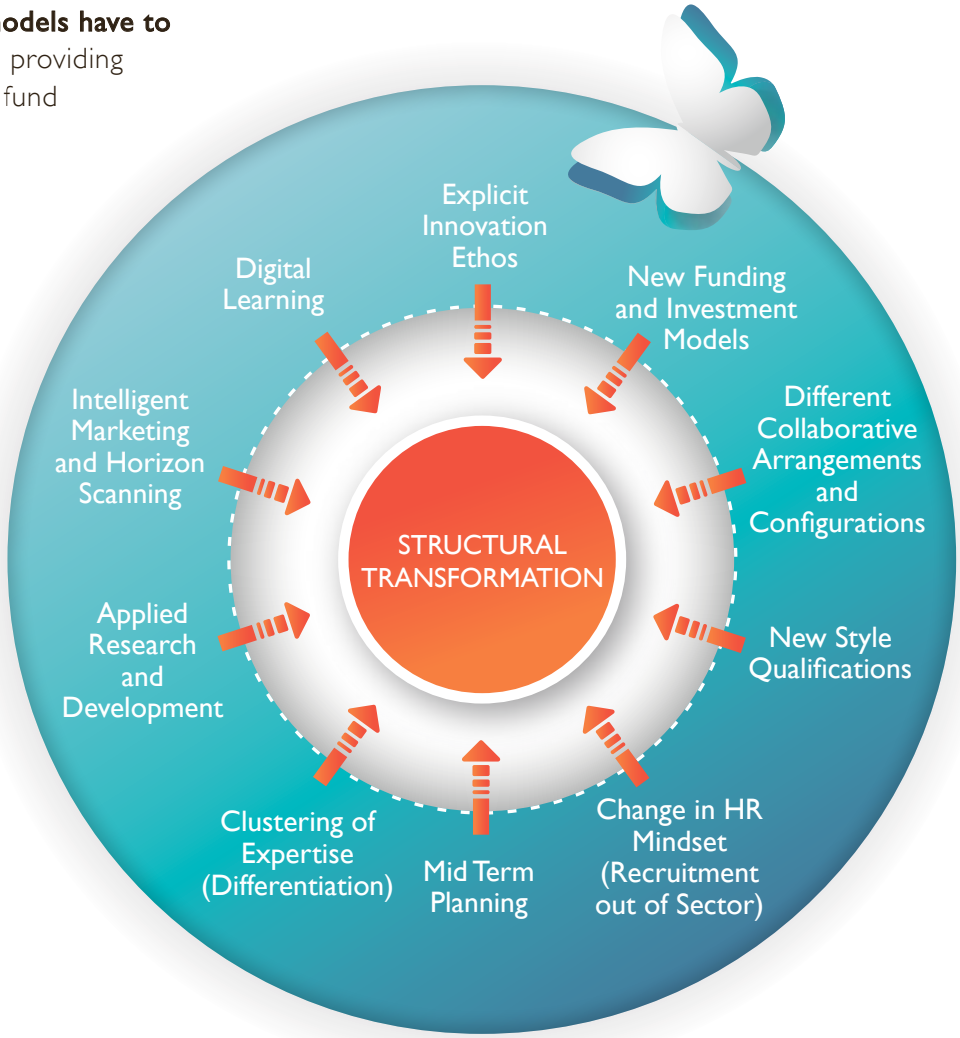
This paper recommends **structural change** in the education eco-system at both a **macro** and **micro** level:

- **Policy and funding mechanisms that could facilitate closer collaboration between academia and industry**
- **Approaches that transform the learning environment for the individual learner**

Exactly how these changes can be most effectively implemented is the next phase of the debate. Our suggestions follow.

[18] *The T-Shaped Technologist*, December 2012, Prof Sa'ad Medhat and Dr Sarah Peers

Structural change in education



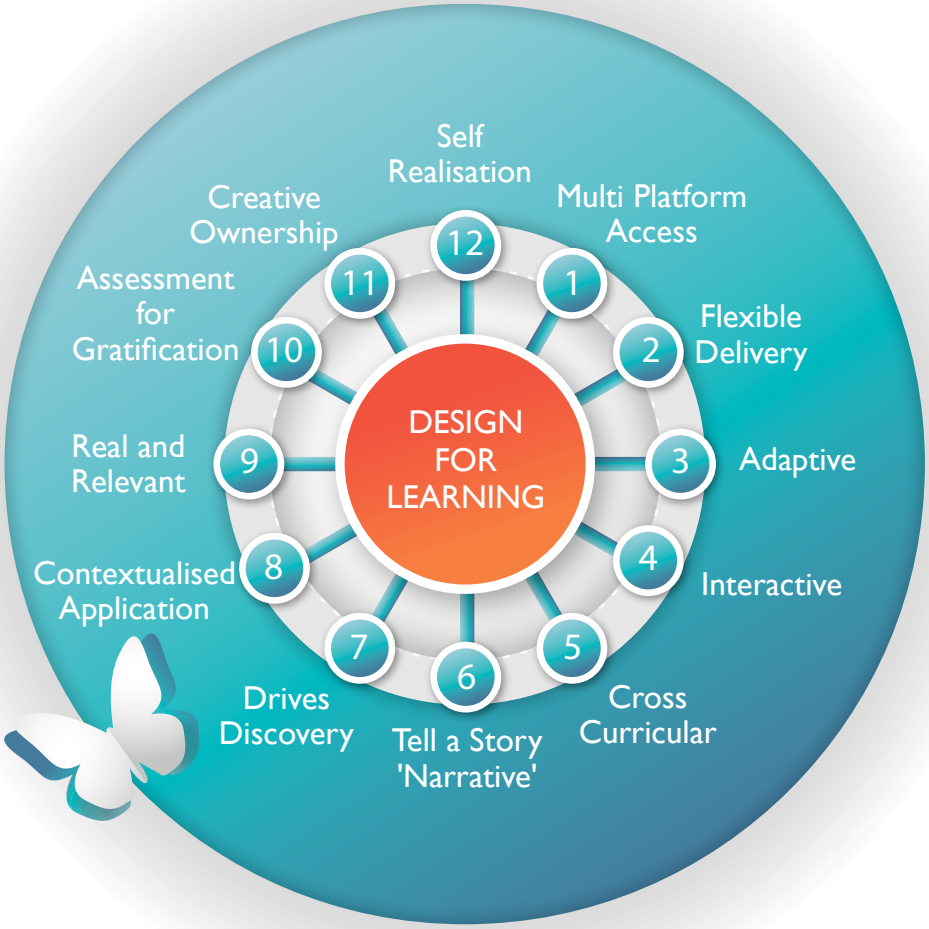
- **New funding and investment models have to be developed** this could include providing tax incentives for companies to fund educational workshops and laboratories that focus on regional skills requirements. The Innovation Tax Credit could be extended to stimulate private investment in STEM education facilities, serving skills needs in different regions
- **Different collaborative arrangements** need to evolve between industry and academia, allowing closer access and exchange of personnel. This could be aided by having local companies represented on college and university boards
- **New styles of qualifications** should evolve. For example, could they be achieved in segments, incrementally at the convenience of the learner?
- **Recruitment in further and higher education must become more imaginative** at present most college and some university HR departments recruit educators from the same sector to fill new jobs. Bringing in people from outside the sector as well as from industry, can encourage new ideas and approaches
- **Planning should become medium or long term** companies often make recruitment decisions based on immediate need. Moving focus to the longer term, and communicating better with local education providers, could help secure the development of the right skills
- **Regional clusters of expertise** could help colleges and universities differentiate their offer to learners, providing a more diverse choice of courses nationally
- The new regional polytechnics could carry out **applied research and development**, supporting local industry
- **Intelligent marketing of courses** at present, many course descriptions appear to be traditional and outdated. They do not communicate the variety of career paths and evolving opportunities attached to the study of different disciplines
- **Horizon scanning** industry could improve its forecasting of technology trends, sharing the information with colleges and universities on how jobs in the workplace are changing
- **Digital learning** should be embraced more actively. From online learning to sophisticated big data analysis that enables adaptive and individualised student learning
- **Innovation** should be central to educational strategy

Design for learning

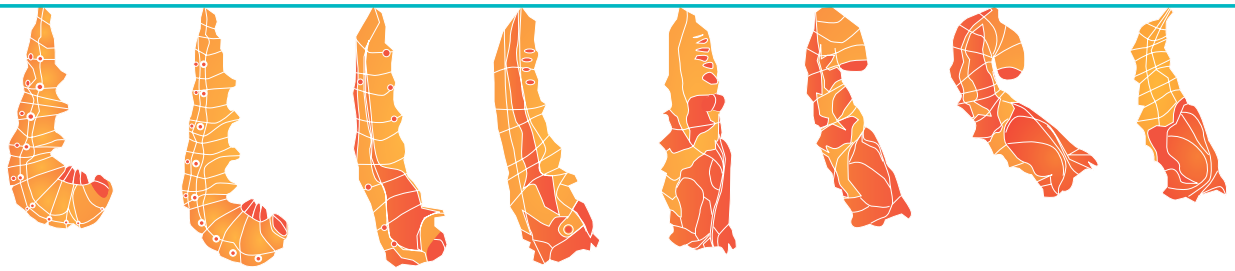
As well as changing the **external** support model for STEM education, it is also necessary to restructure STEM education from within. Here are some recommendations for how regional polytechnics could operate:

Suggestions for transforming the learning experience

- **Multi platform access** as a knowledge exchange hub that embraces open innovation, the polytechnic will need adopt a "collaboratory" approach that enables courses to be co-created and co-assessed with industry, using different collaborative methods and technology platforms
- **Flexible delivery** accredited programmes are highly unitised and available to students in different delivery modes and formats to enable students to access the desired learning when and where they need it
- **Adaptive learning** there should be significant emphasis on creating an adaptive learning environment – this is an interactive type of environment that utilises a wide variety of resources, including augmented reality, that create real-life scenarios for learning. It should enable students to follow different paths and pace their learning to reflect their individual intellectual capability and needs



- **Interactivity** there should be an element of fun and purpose to the learning
- **Cross curricular** courses are no longer separated into narrow silos, but combine several disciplines, creating a workforce that is more interoperable (employees can move more easily between sectors)
- **Narrative** STEM learning should be placed into context so that students understand why they are carrying out certain tasks and how their learning can be applied in the real world
- **Discovery** students are encouraged to make their own discoveries and connections as they learn
- **Relevancy** genuine data or real life scenarios should be used in the classroom and workshop. For example: Nova Labs in the USA is providing high school students with the same data that NASA that professional researchers use, to, say, build robots or track tropical storms. They are mixing fascinating narratives with big data to create a new kind of educational tool. In this way, high school students are able to compete and collaborate with professional researchers, scientists and engineers
- **Context:** students develop awareness of how their learning can be applied across different sectors, applications and situations
- **Assessment:** students receive continual feedback - as if they were playing a computer game – gaining confidence as their competencies develop. The use of gamification will enhance the validation of learning. For example, international education company Kaplan has developed a gamification platform which, it says, can boost student grades by 9%
- **Creative ownership:** creativity is a practical skill. It encourages students to think differently. It makes them become more interested in discovering things for themselves. Students become more effective learners open to new ideas and challenges and are more able to solve problems and work collaboratively, thus developing a greater ownership over their learning. This improves the self-esteem and motivation
- **Self realisation:** self-awareness and realisation forms the foundation of personal growth and success. It is a skill that can be developed in students, leading to a greater sense of achievement and giving them confidence that they are ready to move on to the next level of study, or embark upon their chosen career path



In summary we recommend:

For Government

- The introduction of regional polytechnics and educational community centres
- Innovation tax credits to be extended to include technical skills development as well as specialist capital investment for education
- LEPs to play an integral role in STEM education strategy, acting as an aggregator and monitoring:
  - Skills supply and demand
  - Quality of provision
  - The provision of baseline funding
- Educational levels to be redefined to reflect technological advancement and occupational changes. They should not be used as a proxy for funding allocations

For Industry

- Industry representatives to take a more active role in the governance of technical institutions
- Company representatives to be seconded to or to run technical departments within polytechnics

For Education

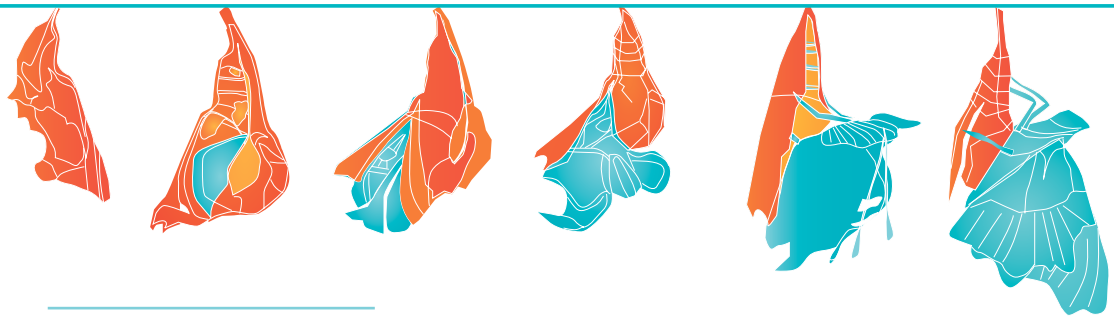
- A flexible approach to learning that adapts to changing industry trends on a yearly basis
- Learning that is interactive and tailored to the needs of individual students
- Courses that are cross curricular - not separated into narrow academic silos
- Students to take creative ownership of the learning process
- Development of technologists with cross-sectoral competencies
- Lecturers and academics to increase participation in industry secondment programmes

POSTSCRIPT: WHY THE BUTTERFLY?

Change is by its very nature, disruptive. It takes people and institutions out of their comfort zones, but as leading evolutionary biologist from Harvard University, Naomi Pierce, will tell you, it is essential for survival.[19]

We have used the butterfly motif extensively throughout this report. Butterflies represent so many things: freedom, hope, metamorphosis, agility and fragility. Scientists remind us that our future is fragile. And industrialists know how agile they need to be to survive. Education can and should offer a metamorphic effect on our future. And the learning experience should be liberating.

By empowering future generations through innovative STEM education we not only safeguard economic prosperity; we also create opportunities to tackle the biggest challenges facing society today.



[19] The Alfred M. Boyce Lecture by the *World-Renowned Evolutionary Biologist to Discuss Evolution of Butterflies and Climate Change* 21 February 2014

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APPENDIX

Qualification levels in the UK[20]

LEVEL	NQF QUALIFICATIONS EXAMPLES	QCF QUALIFICATIONS EXAMPLES		FRAMEWORK FOR HIGHER EDUCATION EXAMPLES
Entry	• Entry level certificates • Skills for Life at Entry level	Entry level VQs: • Entry level awards, certificates and diplomas • Foundation Learning Tier pathways • Functional Skills at Entry level		
1	• GCSEs graded D-G • NVQs at level 1 • Key Skills level 1 • Skills for Life • Foundation Diploma	Level 1 VQs: • BTEC awards, certificates and diplomas at level 1 • Functional Skills level 1 • OCR Nationals • Foundation Learning Tier pathways		
2	• GCSEs graded A*-C • NVQs at level 2 • Level 2 VQs • Key Skills level 2 • Skills for Life • Higher Diploma	Level 2 VQs: • BTEC awards, certificates and diplomas at level 2 • Functional Skills level 2		
3	• AS/A levels • Advanced Extension Awards • International Baccalaureate • Key Skills level 3 • NVQs at level 3 • Cambridge International Awards • Advanced and Progression Diploma	Level 3 VQs: • BTEC awards, certificates and diplomas at level 3 • BTEC Nationals • OCR Nationals		
4	• NVQs at level 4 • Key Skills level 4 • Certificates of higher education	Original NQF Level 4*	Level 4 VQs: • BTEC Professional Diplomas, Certificates and Awards	• Certificates of higher education
5	• Higher national diplomas • Other higher diplomas • NVQs at level 4*		Level 5 VQs: • HNCs and HNDs • BTEC Professional Diplomas, Certificates and Awards	• Diplomas of higher education and further education, foundation degrees and higher national diplomas
6	• National Diploma in Professional Production Skills • NVQs at level 4*		Level 6 VQs: • BTEC Advanced Professional Diplomas, Certificates and Awards	• Bachelor degrees, graduate certificates and diplomas
7	• Postgraduate certificates and diplomas • BTEC advanced professional awards, certificates and diplomas • Fellowships and fellowship diplomas • Diploma in Translation • NVQs at level 5*	Original NQF Level 5*	Level 7 VQs: • Advanced professional awards, certificates and diplomas	• Masters degrees, postgraduate certificates and diplomas
8	• NVQs at level 5*		Level 8 VQs: • Award, certificate and diploma in strategic direction	• Doctorates

[20] Source: Office of Qualifications and Examinations Regulation (OfQual) www.ofqual.gov.uk

INVENTING THE FUTURE: A MACRO-ECONOMIC PERSPECTIVE

STEM industries (industries rich in science, technology, engineering and mathematical skills) are critical for driving improvements in productivity.

As these industries are heavily dependent upon technological change, there is value to be gained in using all means to anticipate or predict change well in advance. If that understanding of the future is communicated to, and assimilated by, training providers through shared working with employers, programmes can be created in a timely manner to deliver the right skills at the right level to both the existing workforce and new entrants to the labour force. The result will be to accelerate the delivery of gains in productivity and, ultimately, to increase the competitiveness of the UK economy and the well-being of its people.

The Role of the STEM Sectors

The relationship between productivity and employment is particularly relevant to any discussion on the performance of STEM sectors – those sectors that require high levels of science, technology, engineering and mathematics (STEM) skills.

Industrial sectors that are rich in STEM occupations differ from many other sectors of the economy through:

- High rates of growth in output
- Improvement in productivity
- Falling levels of employment

This has a profound implication for attracting new entrants to these sectors and the change of occupational profiles within the sectors.

The Current Position

Table 1 shows the structure of the UK economy in terms of Gross Value Added (GVA) output and employment by industrial sector. Manufacturing as a whole accounts for 10.7% of GVA but only 8.4% of employment. The STEM sectors account for 37.8% of GVA and 35.4% of employment. STEM sectors are defined as manufacturing, other production, ICT, transport & storage, and those aspects of the professional, scientific & technical services and health & social care that relate to technical activity.

TABLE 1
UK GVA and Employment by Sector 2011

		OUTPUT (GVA)		EMPLOYMENT	
		£M	% SHARE	THOU.	% SHARE
LOW-MED TECH MANUF.	Food, Beverages & Tobacco	27,771	2.0%	399	1.3%
	Metal, plastic and non-metal mineral products	28,005	2.0%	584	1.9%
	Other Manufacturing	21,046	1.5%	566	1.8%
	Shipbuilding	1,246	0.1%	32	0.1%
MED-HIGH TECH MANUF.	Chemicals	16,926	1.2%	119	0.4%
	ICT & Precision Instruments	8,393	0.6%	138	0.4%
	Automotive	6,955	0.5%	133	0.4%
	Aerospace	5,610	0.4%	112	0.4%
	Machinery, Electrical & Transport Equipment	22,748	1.7%	412	1.3%
	Pharmaceuticals	10,023	0.7%	38	0.1%
OTHER PRODUCTION	Agriculture, Forestry & Fishing	9,122	0.7%	409	1.3%
	Mining & Quarrying	39,646	2.9%	61	0.2%
	Utilities	37,762	2.7%	327	1.0%
	Construction	91,681	6.7%	2,036	6.5%
KNOWLEDGE SERVICES	Communications	23,028	1.7%	227	0.7%
	Digital, Creative & Information Services	61,821	4.5%	1,174	3.7%
	Financial Services	128,830	9.4%	1,116	3.6%
	Business Services	97,528	7.1%	2,235	7.1%
	Research & Development	4,290	0.3%	125	0.4%
	Education	89,676	6.5%	2,722	8.7%
OTHER SERVICES	Hotels & Restaurants	39,601	2.9%	1,990	6.3%
	Retail	71,016	5.2%	3,070	9.8%
	Transport, Storage & Distribution	149,580	10.9%	3,183	10.1%
	Real Estate	98,091	7.1%	417	1.3%
	Administrative & Support Services	65,509	4.8%	2,432	7.8%
	Public Admin & Defence	67,915	4.9%	1,654	5.3%
	Health & Social Care	106,766	7.8%	4,079	13.0%
	Community, Social and Personal services	42,814	3.1%	1,591	5.1%
	WHOLE ECONOMY	1,373,399		31,378	

(Source: Industrial Strategy: UK Sector Analysis, Economics Paper No 18, Dept for Business Innovation and Skills, 2012)

The number of vacancies as a proportion of the existing workforce is 2.4% and of these, 22% are regarded by employers as skills shortages. Their composition indicates, in particular, the absence of a sufficient supply of professional, associate professionals, and skilled trade employees. Due to their occupational structures, the STEM sectors suffer more from skills shortages than the service sectors (see Table 2). The purple cells reflect vacancy proportions greater than 0.1% of the workforce and the orange cells between 0.05% and 0.1% of the workforce.

TABLE 2

UK Skills Shortage Vacancies as a Proportion of the Employed Workforce, 2012

SKILLS SHORTAGE VACANCIES (PERCENTAGE OF WORKFORCE)	MANAGERS	PROFESSIONALS	ASSOCIATE PROFESSIONALS	ADMINISTRATIVE/ CLERICAL STAFF	SKILLED TRADES OCCUPATIONS	CARING, LEISURE AND OTHER SERVICES STAFF	SALES AND CUSTOMER SERVICES STAFF	MACHINE OPERATIVES	ELEMENTARY STAFF
Agriculture	0.02%	0.01%	0.00%	0.01%	0.08%	0.01%	0.00%	0.07%	0.19%
Mining and quarrying	0.00%	0.13%	0.18%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%
Manufacturing	0.01%	0.10%	0.08%	0.01%	0.15%	0.00%	0.02%	0.06%	0.00%
Electricity, Gas and Water	0.01%	0.19%	0.10%	0.01%	0.04%	0.00%	0.01%	0.09%	0.01%
Construction	0.03%	0.03%	0.03%	0.02%	0.22%	0.00%	0.01%	0.05%	0.01%
Wholesale and Retail	0.03%	0.01%	0.05%	0.02%	0.08%	0.00%	0.14%	0.01%	0.02%
Hotels and restaurants	0.03%	0.00%	0.01%	0.03%	0.24%	0.03%	0.02%	0.02%	0.31%
Transport, Storage and Comms	0.01%	0.18%	0.11%	0.02%	0.06%	0.00%	0.06%	0.10%	0.05%
Financial services	0.02%	0.03%	0.09%	0.07%	0.00%	0.02%	0.04%	0.00%	0.00%
Business services	0.02%	0.24%	0.30%	0.10%	0.08%	0.03%	0.02%	0.04%	0.03%
Public admin.	0.01%	0.11%	0.05%	0.02%	0.00%	0.31%	0.00%	0.00%	0.01%
Education	0.00%	0.10%	0.03%	0.01%	0.00%	0.05%	0.01%	0.00%	0.01%
Health and social work	0.01%	0.16%	0.03%	0.01%	0.01%	0.31%	0.00%	0.00%	0.01%
Other services	0.02%	0.04%	0.12%	0.04%	0.02%	0.62%	0.01%	0.01%	0.01%

THE FUTURE

Which STEM sectors will deliver the greatest GVA growth?

Gross Value Added (GVA) measures the contribution to the economy of each individual producer, industry or sector in the United Kingdom.

At the sectoral level, information technology (IT) is expected to generate the greatest growth in GVA and mining, energy & water the least. The remaining STEM sectors are all expected to show growth that is marginally above that of the economy as a whole.

Most sub-sectors within manufacturing are expected to improve GVA: chemicals & pharmaceuticals and the manufacture of base metals & metal fabrication sub-sectors will show significant growth.

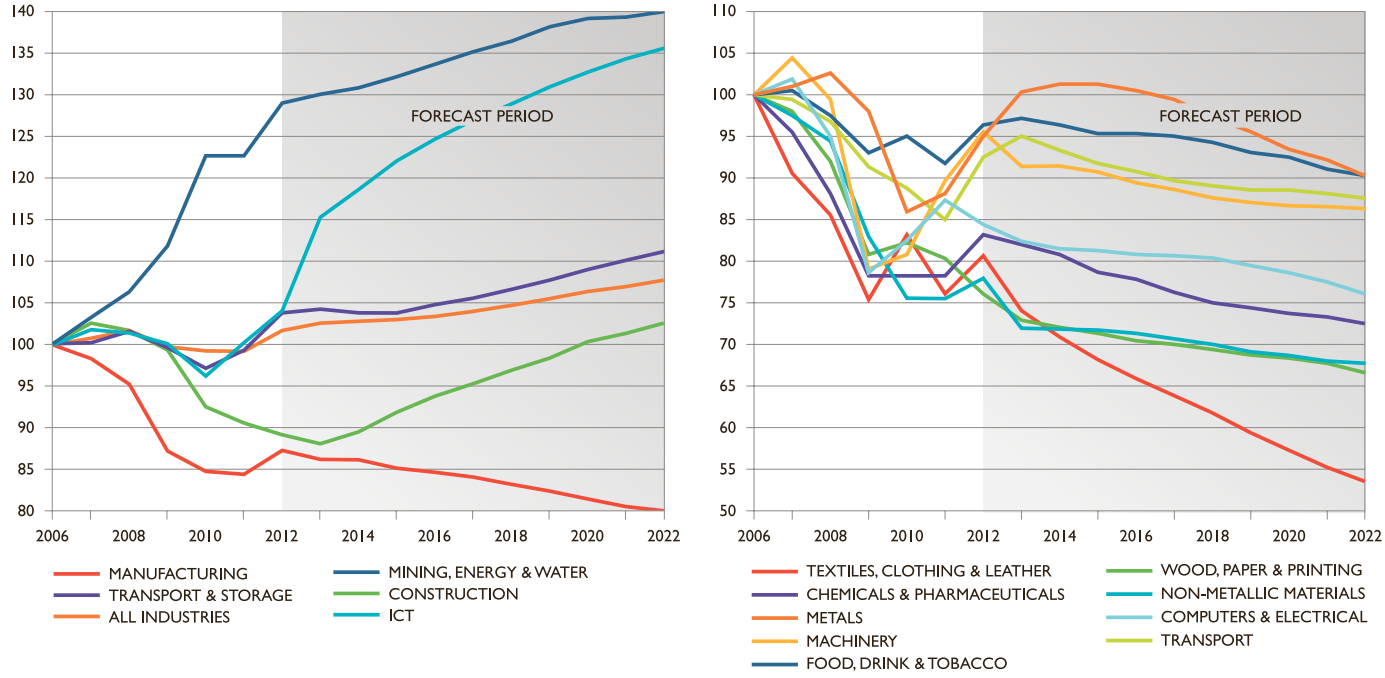
This assumption is either based on the expectation that improvements experienced in the past will continue or that mechanisms will be found to further improve the way in which the workforce will create the predicted growth in labour productivity.

In order to achieve this, there needs to be:

- Effective anticipation of future skills needs
- Adaptive programmes for up-skilling the existing workforce

FIGURE A

UK Index of Employment: Principal STEM Sectors and Manufacturing Sub-Sectors, 2006-2012 and Forecast (2006 =100)



(Source: Working Futures 2012-2022 (2014), UKCES/IER/CE, electronic resource)

Figure A examines the forecast movement in the GVA and employment of both the main STEM sectors and a set of the principal manufacturing sub-sectors.

The purpose is to identify those sectors with the greatest expected growth in either GVA or employment (or both) as they will offer the best opportunity for investment in either technology or skills development aimed at gains in labour productivity.

The data is presented in index form in order to focus attention on the performance within each sector and sub-sector, and away from comparisons that mask differences in the mix of factor inputs. The baseline levels of output and employment were provided by Table 1.

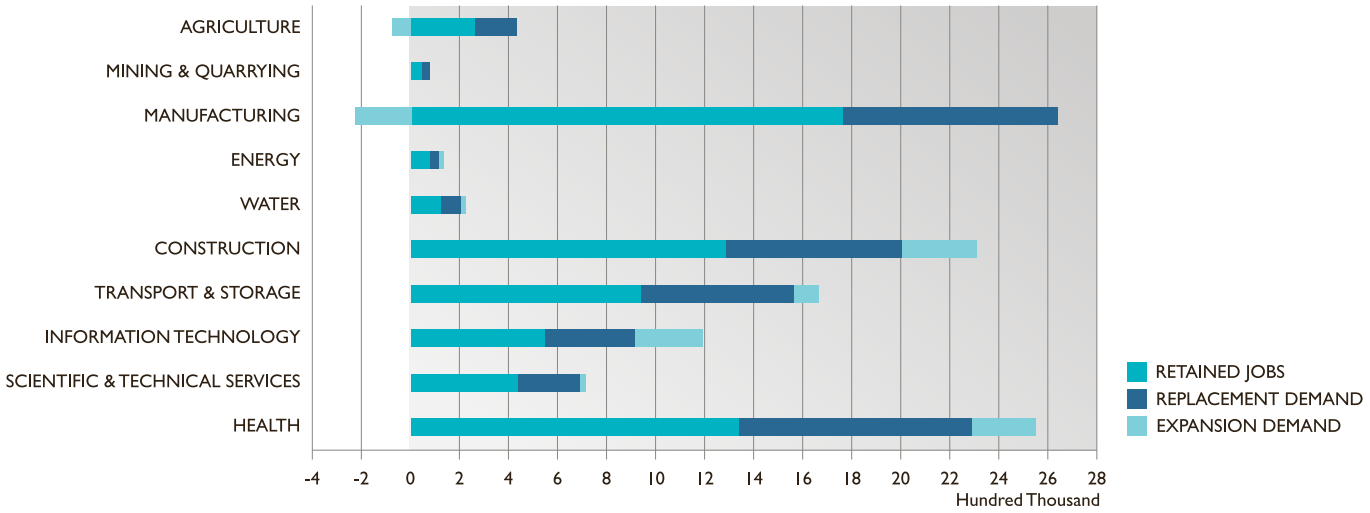
Forecasting future demand for STEM skills

Over the ten year period between 2012 and 2022, the majority of workers recruited to STEM sector companies will be filling replacement jobs, as opposed to newly created ones.

The quantity of **replacement jobs in the STEM industry sectors is expected to be six times greater than the number of new jobs to be filled between 2012 and 2022,** in some sectors, such as engineering, this can be partly explained by an ageing workforce.

The highest replacement ratio is expected in scientific & technical services (13:1), and the lowest ratio in information technology (1.3:1).

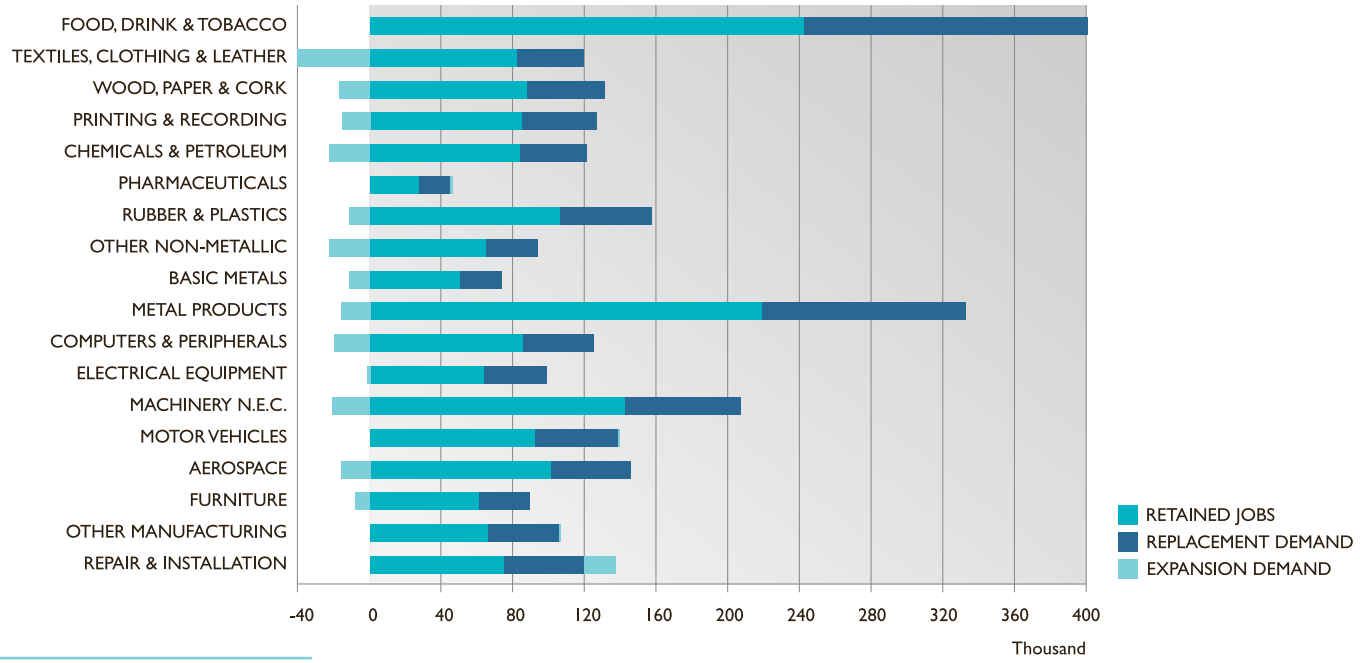
FIGURE B
UK Replacement and Expansion Demand 2012-2022, STEM Industry Sectors



Figures B, C and D[21] reveal the true nature of the demand for labour expected over the ten year period between 2012 and 2022. They show the projected changes in the workforce of the STEM industries, the manufacturing sub-sectors, and the occupational structure of STEM jobs using a "components of change" approach. In order to assess the amount of training likely to be required, both the new jobs and the amount of replacement demand need to be estimated.

Where there is likely to be a net reduction in the total number of jobs, this is shown as a negative value to the left of the vertical axis. The "retained jobs" and the "replacement jobs" taken together provide an estimate of the level of employment in 2012; this value plus the "new jobs" (whether positive or negative) provides a forecast for employment in 2022.

FIGURE C
UK Replacement and Expansion Demand 2012-2022, Manufacturing Sub-Sectors



[21] Source: Working Futures 2012-2022 (2014), UKCES/IER/CE, electronic resource

FIGURE D

UK Replacement and Expansion Demand 2012-2022, STEM Occupation Sub-Groups

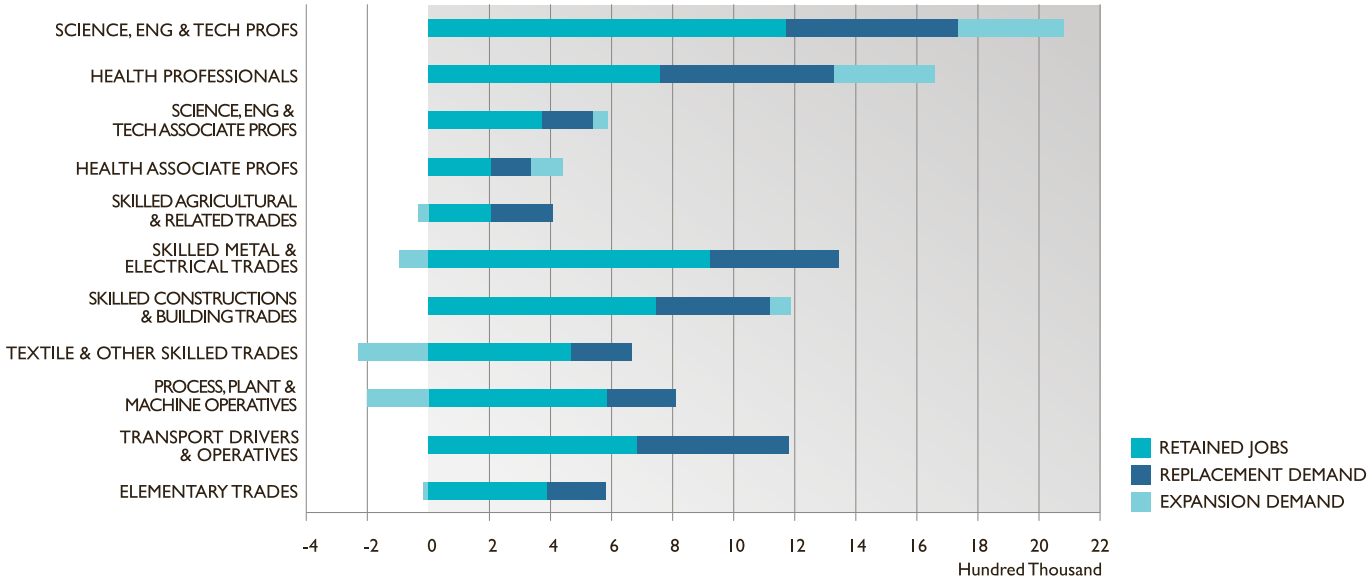


FIGURE E

Occupational Group Shares, Selected STEM Industry Sectors, 2012 (Inner), 2022 (Outer)

Figure E reveals the variation in the occupation profile between different STEM sectors. Information technology will require 74% of its workforce to be graduates by 2022 and advanced manufacturing will require 47%. These two growth sectors demonstrate the increasing importance of high-level qualifications in comparison with the construction and transport & storage sectors.

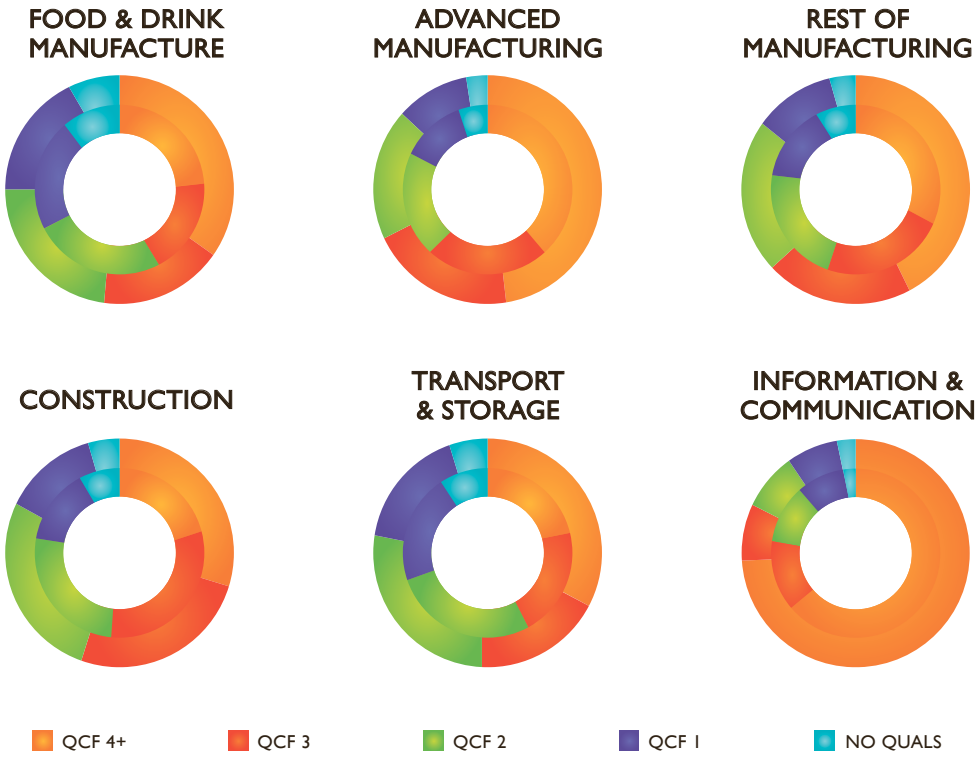


TABLE 3

UK: Labour Requirement by Occupation Sub-Major Groups and Qualification

Table 3 reveals the expected relationship between qualifications and occupations in the total labour requirement (replacement plus new demand) for the 2012-2022 period. The orange and green cells in the table identify the first and second most important qualification required for each sub-major occupation, respectively.

The pattern in the lower occupations is by no means the simple one that might have been expected and must be interpreted in relation to:

- The size of the demand for each occupational sub-major group
- The inclusion of existing qualification holders (60%-75% of total demand) who may be qualified at a lower level than new entrants to the workforce during this period

Level 2 is, as expected, emerging as the minimum requirement for employability. Two occupations are omitted from the colour-coding; textile and printing trades will decline overall and process and machine operatives are expected to show a major shift towards QCF Level 2 as the minimum qualification level.

PROPORTION OF THE STEM LABOUR REQUIREMENT 2012-2022 IN EACH OCCUPATION SUB-MAJOR GROUP EXPECTED TO HOLD QUALIFCATIONS AT THE GIVEN LEVEL									
STEM INDUSTRIES	QCF7+	QCF6	QCF5	QCF4	QCF3	QCF2	QCF1	NO Q	TOTAL (000'S)
Corporate managers and directors	23%	38%	5%	11%	7%	10%	5%	0%	417
Other managers and proprietors	20%	19.82%	10%	8%	20%	11%	2%	8%	74
Science,engineering and technology professionals	41%	32%	5%	10%		5%	4%	1%	432
Health professionals	33%	37%	%	7%	6%	4%	4%	4%	27
Teaching and educational professionals	34%	18%	8%	3%	16%	11%	2%	7%	23
Business, media and public service professionals	34%	43%	2%	5%	6%	4%		1%	183
Science, engineering and technology associate profs	23%	37%	4%	9%	2%	11%	12%	2%	96
Health and social care associate professionals	18%	42%	6%	7%	9%	4%	6%	7%	6
Protective service occupations	22%	46%	14%	13%	-9%	18%	-4%	0%	16
Culture, media and sports occupations	21%	42%	7%	2%	8%	9%	8%	2%	46
Business and public service associate professionals	18%	37%	13%	10%	9%	10%	2%	0%	268
Administrative occupations	10%	29%	14%	10%	18%	7%	1%	0%	250
Secretarial and related occupations	9%	37%	17%	17%	8%	18%	-17%	11%	31
Skilled agricultural and related trades	1%	32%	12%	18%	9%	22%	7%	-2%	93
Skilled metal, electrical and electronic trades	10%	17%	4%	20%	18%	20%	11%	-1%	197
Skilled construction and building trades	3%	8%	6%	9%	17%	42%	17%	-1%	398
Textiles, printing and other skilled trades	-5%	0%	-2%	-5%	32%	28%	18%	35%	-18
Caring personal service occupations	10%	18%	12%	10%	10%	15%	16%	8%	55
Leisure, travel and personal service occupations	4%	22%	12%	18%	24%	17%	-1%	5%	90
Sales occupations	21%	27%	11%	5%	9%	20%	3%	4%	34
Customer service occupations	12%	26%	8%	12%	27%	7%	3%	6%	89
Process, plant and machine operatives	59%	71%	38%	125%	150%	377%	-228%	-492%	8
Transport and mobile machine drivers and operatives	5%	11%	6%	8%	17%	34%	18%	0%	315
Elementary trades and related occupations	3%	15%	7%	8%	15%	32%	36%	-16%	74
Elementary administration and service occupations	4%	13%	7%	5%	17%	44%	30%	-20%	113
All occupations	**17%**	**26%**	**7%**	**11%**	**12%**	**20%**	**8%**	**-2%**	**3,318**

(Source: Working Futures 2012-2022 (2014), UKCES/IER/CE, electronic resource)

Meeting the Challenge

The forecasts indicate a significant growth in demand for those with the highest skills who can fill jobs in the higher occupations. These jobs will drive up productivity in the economy. They have a capacity to use technology and benefit from capital deepening.[22]

However, there are already skills shortages in these top occupations. At the same time, with the exception of construction trades, demand for those employed in the skilled trades at BTEC or NVQ level 3 is forecast to fall.

Managing the balance between labour demand and supply at HNC/D, graduate and professional level is crucial to raising productivity.

The UKCES sees the UK as having, "…too few high performance workplaces, too few employees producing high quality goods and services, too few businesses in high value added sectors."[23]

Fuelling growth in the most productive occupations relies on an aspiration by individuals to progress towards them and an aspiration by businesses that rely on cheap and plentiful labour to raise their market position. Co-ordinated action on skills development could help address these three problem areas.

The CIPD argues[23] that taking into account the wider needs of industry would:

- Encourage educational and training providers to develop more useful skills
- Demonstrate that innovation is not just about technology (against common perceptions)
- Embrace worker-driven innovation that leads to improvement in business processes

It is not only a question of where education, training and up-skilling are targeted as part of progression in the workforce but how that intervention is delivered.

[22] Industrial Strategy and the Future of Skills Policy, Research Insight, CIPD, February 2014

[23] Ibid

CONCLUSION

SUMMARY

- Improvements in productivity will enable the UK economy to return to a period of sustained growth. The role of labour composition is key to maintaining positive changes, year-on-year, in the level of productivity
- The industrial sectors that are rich in STEM occupations contribute a high proportion of the GVA within the economy
- STEM occupations will need to change as technology changes but they must also maintain a capacity to drive the innovation that underpins changes in technology
- A return to growth in productivity depends on a highly qualified labour force, the demands of which can only be met through the progression in qualification and skills of a significant proportion of the current workforce as well as increasing the numbers of new entrants to the labour market with level qualifications
- On current forecasts, the future aggregate demand for labour in STEM sectors may well be matched by supply. However, whether newcomers will have the right level of skills and competencies is more questionable
- New routes will be needed to upskill the existing workforce, as well as industry newcomers, so that they can acquire the qualification and skills required to increase their competency and/or progress to associate professional occupations

The Government's five driver framework[24, 25]

Certain factors are critical for increasing productivity and securing economic growth. The Government's productivity framework identifies five drivers that interact to create long-term improvement in labour productivity secure economic growth:

1. **Investment** in physical capital, machinery, equipment and buildings; the more capital workers have at their disposal, generally the better they are able to do their jobs, producing more and better quality output. **Investment in physical capital** is used as a measure
2. **Innovation** is the successful exploitation of new ideas; new technologies, new products, new corporate structures, and new ways of working. Such innovations can boost productivity. Innovation may be represented by **expenditure by businesses on research and development (R&D) as a percentage of GVA**
3. **Skills** are the quantity and quality of labour of different types available in an economy. Skills complement physical capital and are needed to take advantage of investment in new technologies and organisational structures. Skills may be represented by the qualifications of the current working-age population: the **percentage with no qualifications**, and those of young people, **i.e. the percentage of pupils achieving five or more GCSEs grade A* to C in subjects including English and Mathematics**
4. **Enterprise** is the seizing of new business opportunities by both start-ups and existing firms. New enterprises compete with existing firms by developing new ideas and technologies, increasing competition. Entrepreneurs are able to combine factors of production and new technologies forcing existing firms to adapt or exit the market. Enterprise may be measured by **the numbers of enterprise births and deaths as a percentage of business stock**, and **the percentage of business units surviving for at least three years**
5. **Competition** improves productivity by creating incentives to innovate and ensures that resources are allocated to the most efficient firms. It forces existing firms to organise work more effectively by imitating productive organisational structures and technologies. Competition may be measured by **the value of exports of goods as percentage of GVA**

[24] Oguz S and Knight J, **Regional economic indicators with a focus on the relationship between skills and productivity**, Economic & Labour Market Review, Vol 5, No 2, ONS, February 2011

[25] Dawn Camus (Ed), **The ONS Productivity Handbook, A Statistical Overview and Guide**, Office for National Statistics, Palgrave-Macmillan, 2007

LEADING SKILLS: NEF POINTS THE WAY

In 2011, NEF published ***The Intelligent College***: the practical result has been the establishment of a group of over 50 colleges seeking to put its recommendations into practice.

The network of the Intelligent College has three aims:

1. **Advancing curriculum development**: helping identify curriculum and qualifications no longer fit for industry and economic needs, and facilitating the development of relevant provision in partnership with awarding bodies and/or employers
2. **Driving innovation**: enabling innovation in teaching and learning by facilitating knowledge sharing activities that support the development of contemporary STEM capability and sustainable growth
3. **Articulating the voice of STEM**: The network instigates research and advocates changes to the current thinking of policy-makers, awarding bodies and employers so that voice of STEM is well-represented

The emphasis on the mission of colleges for generating enterprise and social welfare creates fresh impetus for innovation and targets the impact of colleges on the communities that they serve.

Intelligent Colleges build on existing outstanding practice but also take a big step in a new direction – moving from merely reacting to funding, inspection and national initiatives to creating the future through the dynamism of horizon-scanning, enterprise, knowledge transfer and civic leadership.

The paper outlined some of the key features and steps that colleges could embrace on their journey towards becoming Intelligent Colleges. It highlighted the need for changing roles: colleges become a source of innovation and lecturers/teachers become knowledge transfer professionals.

The Intelligent College is a place where emphasis is placed on individual learning through the effective use of well supported e-learning and other advances in learning technologies. Above all, intelligent decision-making requires innovative leadership and strategic governance to create an ecosystem inspiring enterprise and growth while maintaining a customer focus.

The report also highlighted the growing role that the Intelligent College could play in knowledge exchange. Not only the Intelligent College increasingly become a source of innovation, it should also should be a place to turn to for solutions. Colleges provide a framework for the exchange of ideas and the Intelligent College model should be utilised to enhance their full think-tank capabilities.

The Intelligent College can now be seen as the first step to 'Inventing the Future': creating an environment in which the advent of new thinking about future trends will be welcome, digested and used to great effect.

The second step of the journey of transformation is to understand better the innovation process that drives great STEM industry forward. The NEF paper, ***Open Innovation in STEM Learning***[26] looked at how this happens and how such processes could be transferred into the further education sector, particularly via the Intelligent Colleges network.

[26] *Open Innovation in STEM Learning*, NEF, December 2012

Drawing on a wide variety of innovative practice in a range of settings from nuclear power stations and heavy engineering works through to digital and high-tech science industries, the report provided:

1. **Criteria for innovative STEM vocational teaching and learning** setting out the means through which knowledge for industry could be used in education
2. **Industrial case-studies** going into more depth to understand the dynamics of innovation across industry
3. **A toolkit to support colleges** for transferring these innovative practices and to support college leadership in the cultural change that characterised the underpinning force in the industry case-studies

Key themes emerged:

- There is an explicit and clear description of the desirable output from the teaching and learning experience
- There are certain attributes, skills and behaviours in the individual that can be found in NEF's "T-Shaped Technologist" model[26]
- Effective innovation in STEM industry learning embeds a deep understanding of how learning happens. This includes ensuring that the rationale for learning, and its relevance, is clear; identifying the role of trust in teaching and learning relationships; exploiting ubiquitous learning – inside and outside the classroom, formally and informally; allowing learners to take ownership of their learning; taking advantage of technology; and aligning curriculum and assessment to the requirements of the output and that of the real customer
- This provision is shaped by a collaborative effort and influenced by the real customer. It is an ecosystem of learning involving all partners and connecting to the wider community. It fosters open innovation, shared working and resources (people, experts, products and experiences); supports new frameworks and new delivery patterns; enables new pathways and embraces new cross-curricular and multi-disciplinary teaching and learning
- There is a fundamental drive to find new and better ways of teaching and learning
- Education can be said to have succeeded when it inspires and enables. Where a culture for innovation is supported and valued, the result is likely to be inspiring. There is a drive to enhance quality of education, which should support innovation. However, what is not always understood is that failure is often a necessary part of innovation. And what is also clear is the need to identify barriers and enablers: both actual and those that are a product of the system. Processes that are in place to drive innovation will vary as colleges are at different points in their innovation maturity journey, but leadership, structures and support are essential if innovative STEM vocational education is to happen

[27] A White Paper: *T-Shaped Learning for the New Technologist*, NEF, December 2012

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