York & North Yorkshire LOCAL ENTERPRISE PARTNERSHIP

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The Fourth Industrial Revolution and Business Skills Needs in York & North Yorkshire

Produced on behalf of
York & North Yorkshire
Local Enterprise Partnership

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Executive Summary

Les Newby Associates and Nicky Denison/Wordfern Ltd completed this research on behalf of York & North Yorkshire Local Enterprise Partnership (Y&NY LEP) to advance understanding of how skills issues are affecting uptake of fourth industrial revolution[1] (4IR) technologies by businesses in the area and what can be done to support this.

The research explores how far a selection of businesses (focused mostly on medium sized and larger businesses in the engineering/manufacturing sector) are aware of and using these technologies, their associated skills needs, and the extent to which they are engaging with Higher and Further Education (HE and FE) and other educational and training bodies. It also explores the position within businesses supplying 4IR technologies to others; and provides some headlines from an HE and FE perspective. We undertook the research between December 2021 and February 2022, using engagement with 17 businesses, four educational providers and five other organisations and networks. The overall conclusions and recommendations from the research are described in full in Section 5 but in summary are set out below.

Conclusions

Current and future application of 4IR technologies by businesses

- Larger and international businesses and are often forward looking and active in a wide range of advanced technologies including those technologies relating to data and computing, automation, robotics and advanced production. A small minority are at the forefront of their industries, others know much about what is achievable in principle and are moving towards practical application.
- SMEs may use advanced technologies in a few areas that are core to what they do, but rarely have specialists to cover wider areas, and knowledge and application is more limited.
- Engineering and manufacturing businesses tend to use 4IR technologies to help create or produce something physical e.g. via automation and robotics, or the use of innovative new materials. There is some use of additive manufacturing; however, this is often small scale and for prototypes only, because it can be slow and expensive to use at scale.
- Application of cloud computing and data technologies is more common, and businesses expect that application of these technologies will grow further. However, uptake of new technologies that support businesses to extract and analyse data to its full potential is variable.
- Digital technology is intrinsic to developments in agri-tech e.g. in GPS trackers, automated vehicles and precision agriculture. As a result, farms now produce significant amounts of data. However, many farmers do not know how to amalgamate, process and interpret this data in a way that is beneficial to their business.
- Although not widespread, there is some evidence of there being a culture of scepticism towards advanced data and IT technologies within some traditional businesses and amongst some of their engineers. In farming, there is a generational gap between older and younger workers in relation to understanding and willingness to learn and apply advanced technologies.

[1] See Glossary for Fourth Industrial Revolution description

- A good deal of highly advanced digital technology e.g. quantum computing, remains confined to the world of academia and major tech companies such as Google. It has not yet become more mainstream in the way that other digital technologies such as Cloud computing have.

- For many larger businesses, the green agenda is a central driver in the pursuit of new technology and solutions.

- The pace of change in tech is extremely fast and this makes it hard for businesses and educational institutions alike to keep up. Some technologies are perceived as being for *"tomorrow's problems"* and require forward looking businesses to implement them.

- There is scope to consider how businesses and institutions in Y&NY can best collaborate with others active in this space nationally, such as Make UK[2] and university centres of expertise, including in York.

Current attitudes, understanding, skills and expertise

- Many businesses see skills levels in this area as important, sometimes vitally so. Some already have or are developing relevant skills within their workforce, others access them mainly through external suppliers and consultants, and sometimes universities.

- Businesses usually believe that they have reasonable or good awareness about relevant 4IR technologies, although this is often seen as sufficient rather than specialist in nature. Most businesses do not feel they are missing out on opportunities through lack of skills but do see that they are on a learning curve and would like to enhance their skills and understanding. A minority of businesses are more expert, usually larger and international ones.

- In SMEs, understanding of 4IR technologies and their opportunities is often down to one or a few individuals who are interested in this area more than trained experts. Others see that it is mainly an area for younger employees to lead on. Whilst this is a pragmatic response, it can be questioned in terms of the scale and reliability of expertise and whether or not this is an appropriate long-term solution.

- While many businesses feel they have enough awareness of 4IR technologies and their opportunities, it is hard to know how far this perception is sufficiently robust, or whether it may be misplaced in some instances given the range of 4IR technologies and the pace of their development.

Skills needs, issues and shortages

- More than two thirds of relevant companies face challenges in recruiting to highly skilled technical roles. These range from surmountable to severe in terms of how far and easily challenges can be overcome, and their impact on a business. People with the right expertise are highly sought after in a very competitive, global labour market with major skills shortages.

- Examples of hard to recruit roles within businesses using 4IR technologies include software engineers, robotics engineers, data scientists and analysts, as well as roles in Cloud computing, new areas of green technology, and high level biological/chemical expertise.

[2] Make UK is the national industry body for manufacturing https://www.makeuk.org/

- Roles and specialisms where 4IR supplier businesses face skills and recruitment challenges include computer scientists and technical computing skills, coding/software skills, specific embedded software skills, electrical engineers and mechanical engineers, as well as individuals with strong analytical, logic and mathematical skills who can be moulded to specific roles.

- Recruitment is made more complex as businesses are sometimes seeking individuals with multiple skills sets e.g. engineers who also have skills in automation, robotics and digital fields.

- Businesses using and supplying 4IR technologies seek aptitude and capability as well as technical skills. They are looking for people who are creative, practical, can self-learn and are able to apply knowledge in a business setting - and often say that these attributes are lacking.

- Recruitment challenges are greater for businesses in remote locations seeking to recruit young people. Solutions focused on transport and access may be appropriate in these cases. Additionally, shifts to greater online or hybrid working are widening the geography from which companies are recruiting from for specialist roles – across the UK and sometimes internationally.

- From a farming perspective, advances in technology demand skills in digital technology, data analysis, and electrical engineering. However, there are barriers to engaging with and delivering training to time-poor farmers who are sometimes resistant to change.

Connections between businesses and education

- Of the institutions we spoke to, only the University of York[3] is seeing strong and growing demand for advanced technology courses and expects to grow its provision as a result. For others, demand is growing more moderately. This correlates with input that most businesses tended to look towards HE rather than FE for advanced technology skills.

- There are examples of good business-education collaboration. However, there is also a lack of clarity in businesses about the range of courses available across institutions, the skills that they can foster in learners, and how to go about finding an institution that best fits with their needs.

- Educational institutions are keen to develop their links with businesses. However, they perceive that opportunities to do this locally are constrained by the relatively limited numbers of businesses of sufficient scale and technological complexity.

- Integrating content on advanced technologies such as robotics and new digital technologies into apprenticeships and FE/HE courses is important, so that 4IR tech awareness is mainstreamed.

- Educational institutions need to support learners to develop aptitude, capability and practical experience as well as academic credentials and theoretical understanding. A large increase in the number of undergraduate (and other) placements was seen as a good way to foster this blend of academic and hands-on learning, as placements are valued where they are happening.

- It is unrealistic to expect all advanced technology to be taught via HE and FE. Partnerships between education and businesses are essential too, not least because the private sector is better able to provide much of the costly, cutting-edge equipment required. Technology suppliers also have a role to play in imparting good quality information and training.

[3] https://www.york.ac.uk/

- Jobs that demand skills in advanced technologies are typically high quality and well paid. Apprenticeships, especially at degree level, will be one way of ensuring the right blend of academic and hands-on learning, and there are examples of them working well in Y&NY.

- There continues to be a need to shift perceptions amongst learners about the attractiveness of STEM[4] subjects and the careers opportunities they afford. This will be key to tackling diversity issues, including a major deficit in females pursuing STEM based subjects and careers.

Other barriers and issues affecting uptake

- Barriers to greater adoption of advanced technologies include the scale of investment required, high entry costs and the ability to access finance.

- Automation is a long-term shift in the processes of a business and is largely irreversible in nature. Businesses must therefore have a very high degree of certainty that automation is the right solution for them before they are prepared to commit the necessary capital investment.

- Some new products and the technologies must be certified before they can be approved for sale or use. This can limit and slow down new tech based developments.

- There may be issues around wholesale reliance on new technology if this presents vulnerabilities. Some interviewees noted that certain technological changes e.g. on big data and new computing systems, can be prone to cost overruns and long delays.

- We uncovered few if any collaborations between different businesses on 4IR technologies, but some businesses did express an interest in exploring such relationships.

Recommendations and potential ways forward

Recommendation 1: Improve information and awareness in businesses about how educational institutions can help them with 4IR skills needs, expertise and equipment. Solutions may include the use of a shared platform setting out the HE/FE offer, proactive communications, or brokerage to connect businesses to provision. In parallel, improve awareness in relevant HE and FE departments about local businesses active in this sphere.

Recommendation 2: Encourage expanded provision around the most relevant HE courses to provide more skilled graduates, for example in robotics, computer science, cyber security and data analysis, in order to widen the local talent pool, and ensure this is shaped by business demand.

Recommendation 3: Integrate 4IR content into relevant HE and FE courses to help foster and widen technical skills and awareness in the future workforce.

Recommendation 4: Increase demand from young people to study and seek careers in 4IR related subjects/specialisms, including through IAG that fully demonstrates career opportunities, promotion of tech/STEM in education, and focus on diversity and engaging more girls in these subjects.

Recommendation 5: Work with education institutions to radically increase the number of relevant courses that offer undergraduate (and other) placements in businesses applying 4IR technologies.

[4] Science, Technology, Engineering and Maths based subjects

Recommendation 6: Promote awareness and uptake of apprenticeship opportunities in this field, including through raising the perceived value of this pathway and highlighting the potential of degree level apprenticeships to build academic and practical skills.

Recommendation 7: Encourage and communicate provision of shorter and flexible training courses for businesses to upskill employees, as there is likely to be greater take up of bite-size or incremental learning that is manageable within tight financial and time constraints.

Recommendation 8: Explore the potential to develop an advanced technology opportunities assessment service for SMEs. This could involve using advisers with broad understanding of both business needs and relevant technologies to identify opportunities and create links to expertise.

Recommendation 9: Consider the development of a Centre of Excellence for Advanced Technology, or a network of such hubs with different 4IR specialisms, linked to HE expertise, and connected to the Institute of Technology and relevant provision in FE. This would demonstrate and communicate what is possible through application of advanced technologies.

Recommendation 10: Continue to use business and innovation support to create the right environment for commercialising research and the creation of new businesses and university spin-offs. More widely, promote the region's attractive environment and quality of life to help attract high tech businesses and skilled workers, and enhance transport connectivity to jobs in relevant businesses in hard to access locations.

Recommendation 11: Capitalise upon business interest in the green/net zero agenda as a driver for innovation and utilisation of advanced technologies and promote such opportunities to SMEs.

Recommendation 12: Explore opportunities to help businesses with similar technological interests/opportunities to collaborate and exploit potential synergies, e.g. to share or rent out specialist equipment, to build and share expertise, or to seek joint funding.

1. Introduction, Purpose and Methodology

York and North Yorkshire Local Enterprise Partnership (Y&NY LEP) is keen to ensure that businesses have the skills they need to enable them to take advantage of advanced technologies that are leading edge for their sector and type of business and can be considered part of the Fourth Industrial Revolution (4IR).

In November 2021, the LEP commissioned Les Newby Associates and Nicky Denison/Wordfern Ltd to complete initial research into this area, and specifically to increase its understanding of:

- How far businesses are taking advantage of 4IR technologies
- How far they have appropriate awareness, understanding and expertise to make good use of these technologies, and to identify any specific areas where there are skills gaps
- Whether Higher and Further Education (HE and FE) or other training providers can play any further role in meeting emerging skills needs
- Any key barriers to progress and potential solutions, including potential for activities based on business clusters or collaboration.

We discussed potential sectors to focus on with the LEP and the West & North Yorkshire Chamber of Commerce[5] (as a partner in the research) and agreed there would be value in concentrating on two (sometimes linked) sectors: Engineering and Manufacturing, and Food, Farming and Agri-tech.

There is no hard and fast definition for what constitutes 4IR technologies, although in broad terms this is usually considered to be about the fusion of physical, digital and biological realms. The World Economic Forum discuss 4IR both in these terms and in terms of its impact on humanity:

"The Fourth Industrial Revolution represents a fundamental change in the way we live, work and relate to one another. It is a new chapter in human development, enabled by extraordinary technology advances which are merging the physical, digital and biological worlds in ways that create both huge promise and potential peril. The speed, breadth and depth of this revolution is forcing us to rethink how countries develop, how organisations create value and even what it means to be human."[6]

A wide range of technologies can be considered to be part of 4IR. For the purposes of this research, we grouped them into three broad categories:

i) Automation, robotics, artificial intelligence (AI) and machine learning (i.e. technologies focused on machinery and computing that replicates or replaces human attributes)
ii) Advanced digital technologies and data e.g. linked to quantum computing, cloud computing, big data, 5G and the internet of things
iii) Other advanced technologies including new production technologies i.e. that improve production processes and/or products and not captured in i) and ii) e.g. nanotechnology, additive manufacturing, use of new materials, or advanced green, energy or transport technologies.

Very often these categories are connected, and we have used them as a practical tool for breaking a long and complex list of technologies into groups that are easier to communicate and report on,

[5] https://www.wnychamber.co.uk/
[6] https://www.weforum.org/focus/fourth-industrial-revolution

rather than any hard and fast definition. Financial Technologies could be included, however, the companies we engaged with did not talk about this and hence it is not covered in this report.

We undertook this research between November 2021 and February 2022, targeting interviews with:

a) Businesses who are 4IR technology users or who would expect to be in the near future
b) Businesses who provide/supply 4IR technologies to others ('4IR suppliers')
c) Other organisations and stakeholders with relevant expertise and insights – including HE and FE, the Y&NY LEP and the West & North Yorkshire Chamber of Commerce.

We are grateful to the West & North Yorkshire Chamber of the Commerce, the Y&NY LEP, North Yorkshire County Council, City of York Council, KADA Research and the North Yorkshire Learning Providers Network for helping to identify and contact businesses. Table 1 summarises those we engaged with in each category, usually through semi-structured online interviews. Additionally, we engaged with the Yorkshire and Humber Apprenticeship Ambassador Network which brings together 60 businesses in the region, including nine in Y&NY as a route to gain wider inputs. We formulated a short online survey that was sent to this group in January 2022 and the results complement and triangulate with our main findings which are based on the interviews completed.

Finally, we note that there are parallels between this research and previous research commissioned by the LEP, notably into Digital Skills,[7] and to a lesser extent into Low Carbon and Circular Economy Skills.[8] Where appropriate we cross reference this research with wider research in the region. There are also potential connections to work on priority sectors in Y&NY and to skills issues such as progression and high performance working. We collaborated with consultants (KADA Research and Annabel Jelley in partnership with Tokos Solutions) leading studies into these areas.

Table 1: Breakdown of interviewees by type

Type of Stakeholder	Number of organisations interviewed
4IR business users	12
4IR suppliers	5
Universities and Further Education Colleges	4
Representative bodies, network leads and experts*	5
Total	**26**

* Y&H Apprenticeship Ambassador Group, Chamber of Commerce, YNY LEP, NY Learning Providers

This report draws out the main messages from our engagement with sections on:

- Overall application of 4IR technologies by business
- Skills and wider issues in these businesses that influence uptake
- 4IR suppliers and their skills issues
- The position, assets and role of HE and FE
- Overall conclusions and ways forward, including the potential of clustering and collaboration.

[7] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20Digital%20Skills%20report.%20%20Publication.%20Apr%2021..pdf
[8] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20LC&CE%20Skills%20report.%20%20Publication.%20Feb%2021.pdf

We also provide two case studies (see Annex A), gathered from companies that we engaged with in this research, which demonstrate how 4IR technologies are being applied in practice and how businesses are responding to associated skills issues.

We would like to thank all the contributors for their support, time and insights. We have included quotes from interviews to reflect views without directly attributing them.

2. Application of 4IR Technologies in Businesses

As outlined in the introduction, our research used a broad segmentation of three types of 4IR skills to assess current and future application in business, based on:

i) Automation, robotics, artificial intelligence (AI) and machine learning (i.e. technologies focused on machinery and computing that replicate or replace human attributes)

ii) Advanced digital technologies and data e.g. linked to quantum computing, cloud computing, big data, 5G and the internet of things

iii) Other advanced technologies including new production technologies i.e. that improve production processes and/or products and not captured in i) and ii) e.g. nanotechnology, additive manufacturing, use of new materials, or advanced green, energy or transport technologies

Our analysis uses these categories to describe current and future technology uptake by the businesses with whom we engaged. Section 3 then explores skills issues in relation to them.

2.1 Automation, robotics, artificial intelligence and machine learning

2.1.1 Current application

We asked those interviewed to what extent they were currently employing these technologies in their businesses. The response varied and tended towards higher usage of automation and robotics than AI and machine learning.

Two large companies described their use of automation and robotics as very high and central to driving the large-scale efficiencies. As one noted: *"we operate in a very technologically advanced sector, and we are at the forefront of this – we have very advanced understanding and application, and this will continue given the huge gains to be had."* These businesses were the only ones to discuss in any substantive manner their current use of AI and machine learning, with one making it intrinsic to their ability to push forward their automation ambitions: *"the data we capture and analyse is critical to making our automated machines as efficient as possible."* The other used it to a lesser but important degree in an automated design process.

A further small group of businesses had a good deal of current application. One had looked across their entire production system and introduced as much automation (and digitisation) as possible, in their view making around 85% of their process automated. Another used a lot of advanced instrumentation and robotic equipment in their laboratories; and a further had just created their first robotic factory for welding and painting. They described this as their first step into robotics but one they are looking to replicate in their two other factories.

The Chamber of Commerce noted that thinking on 4IR technologies in many businesses, including SMEs, is changing. This included being prompted by Brexit and Covid-19 related sharpening of supply chain arrangements and labour challenges:

"Everyone's thinking of automating now…we're on the verge of a revolution [in using tech]."

This change and advancement was reflected in the businesses we interviewed, where some had made important steps into tech application and automation. For example, one was using

automation for remote monitoring of waste, and another had appointed two new staff with responsibility for three new robots in the business.

We discuss non-skills related barriers to uptake in more detail in section 3.4, but it is important to note here that a number of businesses with lower levels of current use felt themselves to be constrained by the nature of their business. For example, one business did not produce in the volumes required to benefit from or offset the scale of investment required; and two others described themselves as too niche or specialist, i.e. they provide small scale, one-off solutions rather than production line products and this by its nature is not meaningfully served by robotic or automated solutions (see Glossary for explanation).

2.1.2 Future application

Intentions on future application follow a similar pattern. The two businesses at the forefront of current application are also at the front of future application. One has a pipeline of automation projects identified, and goals to do more on AI and machine learning linked to product design. The other was equally clear that that their work in this area would continue at pace, however also noted that: *"we will never completely remove the need for humans – they are a big part of safety, and you need people to make sense of the data."*

The group that had made more modest steps forward plan to see this gradual trajectory continue, incrementally increasing application: *"we plan to automate more production processes if possible. We have done the hardware side, now we need to look at the software side."* Emphasis included a business strategy to replace repetitive, mundane work with robots allowing people to focus on higher value, higher skilled tasks. We heard of a number of projects on the horizon, including working in partnership to build a controlled factory where there will be substantial use of robotics and machine learning. We also heard how one company saw themselves as being on the cusp of receiving orders at scale and that this would allow them to do much more on this in the future. They had begun to liaise with the University of Sheffield AMRC (Advanced Manufacturing Research Centre)[9] and The Welding Institute (TWI)[10] in Sheffield, as well as Sharing in Growth (SiG),[11] as a route to taking this forward, but were eager for more support on how best to invest and install equipment in their company.

"Our near future is about greater automation. It is the first step for our Vision 2025; AI is for 2025-30 – we are talking about it but not doing anything about it yet."

The remainder of businesses were open but non-committal, suggesting that moves in this direction were not a priority. For one, whilst they were positive about the role of these technologies in improving resource efficiency and productivity, they saw decisions being taken at their international site and perhaps had less autonomy to make a local decision. Another could see how some processes could be automated but felt that it would be better to sub-contract this work rather than lead on automation internally.

[9] https://www.amrc.co.uk/
[10] https://theweldinginstitute.com/
[11] https://sig-uk.org/

2.2 Advanced digital technologies and data

2.2.1 Current application

There is far more parity across businesses in terms of understanding and then applying this grouping of technologies, although again, this tends to be clustered around some components of our definition – those being cloud computing and data.

Only two of the businesses we spoke to described themselves as doing very little or nothing, with one going so far as to say: *"we don't see the relevance to our business and have no plans to change that in the future."*

Beyond these, we heard of a wide and varied range of applications, with data and its collection, analysis, use and storage being a central theme. People spoke about *"everything moving in this direction,"* both in terms of their own business efficiencies and progress, and in respect to their industry and its evolution. For the latter, this included one business working on a SMART Cities[12] project with demands for high levels of data and open access to it.

From an agri-tech perspective, there was, however, a note of caution. We were told of there being a race in the sector to carry out very large scale data projects, with it having become a very crowded space with *"lots of companies and initiatives that all start with great expectations but with most underwhelming in reality."* One interviewee had experience of investing in and launching a substantial data project that had been halted as it was not delivering the return on investment required. They have put on hold plans to carry out more work in this area in the future, instead choosing to focus on other market drivers, observing that:

"At a strategic level, big data projects are an easy concept to sell and very seductive, but they can be elastic and go from one hill to the next, whereas you need returns to justify them carrying on."

Beyond data, for most businesses, the biggest area of change has been in the shift to cloud computing. There has been rapid acceleration in adoption and application in recent years in this area. One business told us about how it had bought in and embedded a business-wide workplan system that amalgamated ten disparate systems into one, with that having been a great success. Another described how *"the change has been unbelievable over the last five years"* with a full shift to a cloud based system that deals with all aspects of the business. This was seen as being *"a massive development for us",* allowing remote monitoring of customer machines and thereby removing the need for site visits. Their progress has resulted in them being listed in the Digital Enterprise Top 100 Companies[13] for two years. This gave an overall impression that many businesses have accepted the role of these technologies and are doing what they can to respond at a pace that is appropriate for them.

"We have made great strides – from nothing two years ago to now being 85% of where we want to be."

"We have modern operating systems now – we try to be leading edge, but not bleeding edge."

Only three businesses talked about their application of technologies around the Internet of Things (IoT), 5G and quantum computing. A good deal of the latter is based around highly advanced digital

[12] https://ec.europa.eu/info/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en
[13] https://www.digitalenterprise.co.uk/top100/

technology which remains largely confined to the world of academia and major tech companies such as Google. It has not yet become more mainstream in the way that other digital technologies such as cloud computing have.

One interviewee was the most advanced in this field, albeit speaking of their global operations rather than solely about what is happening in Y&NY. Applications included extensive use of IoT and some use of 5G where internet connectivity is weaker or less stable. Even for them, however, quantum computing was not being used – *"when it becomes more mainstream, we will use it if it will be helpful."*

Another business was using very advanced computing power and expertise through a Knowledge Transfer Partnership with the University of Leeds focused on modelling, performance improvements and waste reduction. Finally, we heard how one business was ensuring that its new products were compatible with 5G but noted that this had caused complications on product specifications when looking to export to multiple nations all at different stages of their 3G/4G/5G journeys.

2.1.2 Future application

All bar one business spoke of their future application of this category of technologies as a given and as constant. This included building on steps already taken to digitally transform in order to further rationalise, modernise and centralise systems and processes; to extend use of data and management information systems to inform decision making; and to enhance the interface with customers. One company told us that they had commissioned Deloitte to help them understand where they currently sat on the digital maturity curve, and that their future trajectory in this area therefore focused on moving up the digitisation trajectory, and specifically to use these technologies to *"join the dots in our operations to the fullest extent so that the journey from customer to product is as seamless as possible."*

On IoT and 5G, a minority identified this as a possible avenue for the future but that this would be entirely driven by customer demand, which as yet was insufficient. Another barrier was identified in the form of the need to gain international certifications, which can be a slow process and limit new developments.

2.3 Other advanced technologies

2.3.1 Current application

The current application of other advanced technologies was more sporadic, with few interviewees giving notable examples of application. People typically deemed these technologies to be low on their agenda unless they were clearly related to the nature of their business (or sometimes to it achieving net zero carbon goals), in part due to barriers such as cost or decisions being taken at a headquarters elsewhere.

A small cluster did however appear around application of innovative and advanced green technologies, with carbon targets and carbon neutral ambitions noted as key drivers behind this. Two businesses involved in modular construction were active in this area. For both, there has been significant innovation in design and materials choices to assist the shift to low carbon/net zero buildings. Both were working in partnership with Yorkshire based Universities (Leeds and Sheffield), on a variety of projects including development of a self-sustaining eco-module and in work to reduce steel weight by 15% whilst at the same time strengthening construction. Other

activity included developing six small scale zero operational carbon sites with more planned; and work with suppliers to innovate and improve their products.

Application was also advanced in this area in agri-tech, based on biological/chemical expertise and innovative technologies and methods for food/protein production and net zero progress. One example given focused on the use of new technologies to support a circular economy. This allows a substantial range of food and agricultural waste to be transformed into valorised products, e.g. for feeding fast growing insect larvae that can become protein rich livestock feed or supplements. This reaps benefits in terms of finances, livestock health, waste reduction and replacement of soy that in turn reduces deforestation and carbon emissions. As the interviewee noted *"this is our core business, and we will continue to be advanced in this area in the long term."* The focus on green technologies was also a priority in respect to the use of hydrogen to power fleet and machinery.

There was some application of 3D printing, but its use tended towards prototyping and modelling or small scale and specialised orders rather than full scale production, where it is often faster and more cost effective to use other processes. There was, however, one example from a manufacturer who is using additive printers and manufacturing in producing some aircraft parts, both in prototype and end product forms. This company was also beginning to do more on nanotechnology.

2.3.2 Future application

There is a limited amount to report on in regard to future application. In essence, those who are not currently working in this area think that they are unlikely to start doing so in the short to medium term; whereas those who are, will continue to do so. For those focusing on green technologies, there is a clear imperative to continue to develop their products and services in this way, notably in terms of staying relevant, successful and competitive in their sectors.

"We will constantly seek to improve – we see green products and energy as crucial to our future success."

There are barriers to doing this though, for example around securing certification and limited awareness of opportunities. A lack of other companies nearby who are applying the same technologies was also seen as a block on potential collaboration, and as one company noted *"it would be good to know who else was working on nanotechnology so we can see if there is synergy."* *Section* 4.4 covers wider barriers to application in more detail.

3. Skills and Wider Issues Affecting Uptake of 4IR Technologies

3.1 Overall perceived importance of 4IR skills and expertise

The majority of businesses who use advanced technologies see skills and expertise as pivotal to their application. Those we talked to typically described them as *"hugely important,"* while one went so far as to say that *"skills and talent is everything for us."* So, it is clear that having the right skills in place is a key underpinning requirement or driver for application of advanced technologies in many businesses.

Two factors nuance this finding about the importance of skills. The first is that some businesses tend to conflate the general importance of specialist skills in their workforce with specialist skills in advanced technologies. For example, in a manufacturing SME, it may be that they are seeking individuals with both core engineering skills, and the ability to spot opportunities for or apply 4IR technologies such as automation and robotics. Hence, their description of skills as hugely important tends to reflect a combination of both skill sets.

Secondly, for some businesses that use advanced technologies, skills are important, but not necessarily about the skills of their own workforce. This was the case for a significant number of the businesses we talked to, who relied upon suppliers of new technology or specialist consultants as their prime source of expertise in applying 4IR solutions, or sometimes their headquarters (HQ) or a university. As such there is interconnection between skills availability and issues in businesses who use advanced technologies and those who supply them (see 3.2).

3.2 Current skills and expertise in 4IR technologies

Overall, there was a reasonable and sometimes very good level of overall awareness and understanding of 4IR technologies and their potential application, and this is discussed below. However, it is important to say at the outset that this reflects the position in the mainly medium to large sized businesses we interviewed, and not necessarily that of smaller SMEs. In that respect, conversations with representatives (including the Chamber of Commerce) made clear that while large companies *"are doing some interesting things,"* many SMEs are struggling with 4IR technologies. Previous research on digital[14] and low carbon technologies[15] also reported awareness and uptake of these to be more challenging for SMEs.

It is also clear that there is interconnection between larger and smaller companies on this agenda, where large businesses are seeking 4IR related innovations and products from their suppliers (e.g. incorporation of sensors for IoT functionality) which creates tech pressures for them to respond to.

Automation, robotics, AI and machine learning

Most of the businesses interviewed perceived their own levels of understanding and awareness around this group of technologies similarly - which was that their skills and awareness are *"reasonable"* or *"good enough for what we need."*

[14] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20Digital%20Skills%20report.%20%20Publication.%20Apr%2021..pdf

[15] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20LC&CE%20Skills%20report.%20%20Publication.%20Feb%2021.pdf

Businesses sometimes specifically recognised that they are on a learning curve in this area and that while their skills may be fit for purpose, improving them would be helpful:

"We're not missing out on opportunities through a lack of knowledge in this space, but we could always benefit from more."

Interviewees were often demonstrably knowledgeable about the types of technologies that might in theory be applied, and the reasons why they may or may not be suitable for their business, without being expert in the detail. As also arose in the findings of previous digital skills research[16] in Y&NY, some recognised that *"we don't know what we don't know."* Furthermore, the extent of expertise in medium sized businesses was often restricted to one or a few key people. Sometimes this was down to a keen director or engineer with an interest in technology, and in other cases there was explicit reliance or expectation that young people were the solution to technical skills needs:

"Young people pick it up quickly, their mindset is more attuned to using tech."

"How we use tech is down to bright young things with a head full of ideas, but it's getting harder and harder to find them."

These lead people were sometimes then relied upon to train others internally and seen to keep on top of things through self-learning and keeping track with developments. Whilst this pragmatic model based on finding a way through was thought to be working reasonably well for those who applied it, there are risks involved too. Much of that is about vulnerability and resilience. Reliance on individuals who could be at risk of moving elsewhere given a tight labour market may create real problems should they leave. Likewise, how far a director or other individual who is on the face of it *"pretty clued up"* has deep enough knowledge to make potentially crucial decisions on complex and rapidly evolving technologies may vary.

In addition to the main group of businesses who said they were sufficiently expert, two large businesses said that their expertise in 4IR technologies was more developed. One described it as *"very advanced,"* while the other said it had benefited from a recruitment strategy which had brought in people with good skills in this area from other manufacturing companies outside the region where relevant skill sets had been in place.

Advanced digital technologies and data

Most businesses have at least a broad awareness of opportunities but lack specialist skills, and typically rely on others to bring in and manage new digital, data and computing applications and systems. For companies where their Y&NY base is one part of a bigger and sometimes global operation, which can include using expertise within their group, for example from a HQ elsewhere.

The tendency for companies without such a resource to outsource skills and expertise, or to rely on *"a clued up director*" or other member of staff was echoed, and if anything greater, for digital, data and computing skills and advances such as moves towards cloud based systems, which was the most commonly cited technology in this area. This also included examples where one member of staff would learn or gain training in a system and pass that on to others.

[16] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20Digital%20Skills%20report.%20%20Publication.%20Apr%2021..pdf

"We're OK, but more through luck than judgement. We have an engineer who is very interested in tech, and another employee who lives and breathes software."

Aside from the middle ground of those who had reasonable but not expert understanding, there were examples of companies with skills at the poles above and below this. One international company was confident that it had very good awareness in this area, while at the other extreme a company was well aware that it was lagging in this area, even though they did not judge it to be of high relevance to their business:

"We have lots of very clever engineers, but we're desperately unskilled on IT."

Beyond the companies interviewed directly as part of the research, we gained observations about how this tech was being applied in businesses in the region more widely from those had insights around this. In this respect, one noted that there is *"an element of fear around the digitalisation of certain things"* and that some struggle with the idea of the Cloud and where information goes and is stored. Other studies have also reported culture as a barrier to digital skills. For example, research by Cranfield University and Vendigital[17] found resistance to change to be as important as a lack of digital skills and that *"from a cultural perspective, some businesses are struggling to make digital transformation an empowering experience for employees. Some may feel that their jobs are being undermined by the digital technologies under trial, rather than viewing their introduction as an opportunity for skills development."*

The results of previous research into digital skills needs[18] are also highly relevant and reinforce the findings here as well as reflecting issues across a wider spread of SMEs. Key points include:

- Areas of digital skills needs within businesses include cyber security, web development, e-commerce and analytics.
- Most SMEs are too small to have digital specialists, and digital responsibilities are often bundled into existing roles. They hence seek general uplifts in digital competence and ability.
- Lack of digital expertise makes it hard for SMEs to know exactly what their digital skills needs are, how to address them, and what provision they need to solve practical business issues.
- Digital training in SMEs is often in-house or via external consultants for specific technical tasks. Any external training is preferably bite-sized or modular to fit financial and time constraints

Other advanced technologies

For other advanced technologies including production and materials based tech, the position has similarities to other technologies, but sees more businesses at each extreme on the spectrum of understanding – which reflects their uptake of these technologies (as discussed in section 2) and their perceived relevance.

One group of companies whose core business is around manufacturing/producing physical products reported excellent skills in this area because it so pivotal to their success. These had good in-house skills and awareness and sometimes added to these through collaboration. For example, one

[17] https://www.imeche.org/news/news-article/funding-digital-skill-gap-and-resistance-to-change-holding-back-industry-4.0-in-uk

[18] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20Digital%20Skills%20report.%20%20Publication.%20Apr%2021..pdf

company was working with the University of Leeds[19] around modelling to support development of new, more efficient and greener (combinations of) materials. Another had developed leading-edge practices and related expertise in the mining sector, linked to advanced green technologies as well as to data.

At the other end of the spectrum, a number of companies did not see other production and other 4IR technologies and skills related to them as particularly relevant to their business (beyond the automation/robotics/AI group already discussed). Some of these focused on servicing and maintenance from their Y&NY bases and had main manufacturing plants elsewhere – where they anticipated these technologies and the skills for them would be used. Others had the skills to apply certain technologies, such as for the use of additive manufacturing in prototyping, and thought that they had enough awareness of other technologies to know they were not relevant to themselves. How far this is definitely the case for all such businesses is in reality unclear, given incomplete awareness of available technologies and their future application.

Finally, it is clear that the climate emergency (and carbon targets) and broader green agenda is driving the adoption of technology and related skills in many businesses. The research uncovered excellent examples of innovation in this area (see section 2) and skills and awareness, as well as corporate decision making, underpin realisation of these ambitions. Previous research published by the Y&NY LEP on low carbon and circular economy skills is also relevant[20] here and in relation to skills needs and ability to access them.

3.3 Skills gaps and ability to access and build 4IR related skills

3.3.1 Extent of skills gaps and challenges

Interviews revealed a mixed position in terms of the difficulty of recruiting or upskilling staff with the skills needed for advanced technologies. Three broad groups emerged in this respect, with perhaps the mid-way position being companies who said that the specialist skills they need are a challenge to recruit but not an insurmountable one or a major problem. A second, smaller group of companies said that they were recruiting the roles they needed without much difficulty, and that in some cases recruiting to other roles was more difficult, including basic and management roles.

However, another group of businesses are experiencing real difficulties in recruiting for key technical roles:

"*The market we're in is on fire at the moment, it's not easy to recruit*."

"*Every company [in our sector] needs these skills so competition is fierce."*

This means that over two thirds of the businesses we interviewed are facing significant or serious challenges in recruiting to highly skilled technical roles. Some of these are further compounded by or interrelated with longstanding skills challenges in recruiting to other key roles such as for engineers and in technical construction roles such as electricians and plumbers where there is "*a huge amount of people going after them*". New areas, such as green/low carbon related skills further add to the complexity of the challenges and competition for people.

[19] https://www.leeds.ac.uk/

[20] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20LC&CE%20Skills%20report.%20%20Publication.%20Feb%2021.pdf

Reflecting this bundle of future challenges and opportunities, we found that businesses would quite often be seeking individuals with two or more specific skill sets. Examples include engineers with 4IR related technical skills such as in automation; engineers with good qualifications in physics/maths plus software skills; and sales staff with technical skills. This adds to the difficulty of recruiting and can also mean that if the right person with both skills sets cannot be found, it is the core skill need (e.g. for an engineer) that is likely to win out over the seemingly less critical and immediate need for 4IR skills. The implication for education and training is the need for courses that foster multiple skills and integrate elements of 4IR skills into core courses such as engineering, in a similar way in which it is recommended that low carbon skills are seeded into courses.

Besides these complex skills needs, there are also some clear-cut specialisms and roles where skills gaps exist. Whilst the sample of businesses we interviewed is neither broad or large enough to be categoric about these (it mainly reflects medium and large engineering and manufacturing businesses), specific roles where businesses identified difficulty recruiting included:

- Robotics engineers
- Data analysts and data scientists
- Cyber security specialists
- Experts in new areas of green technology (e.g. hydrogen related)
- Scientists with high level biological/chemical expertise (relevant to food/agri-tech)
- Cloud based skills (although those were often gained through external companies)

Research and engagement with businesses often finds them to be seeking recruits with the right fit with their company in terms of attitude, aptitude and transferable skills as well as technical ones and qualifications. This was also the case in this research. For example, one business talked about needing *"state of mind skills"* such as a can-do attitude as well as technical ones, while another stressed that *"if you have the right management skills, knowledge and behaviours you can work the rest out."*

A number of other barriers added to recruitment challenges. For less well-known companies and SMEs, these included a tendency for young people to want to work for a big company with a brand that they know. Likewise outdated perceptions of apprenticeships (including - and perhaps most notably - amongst parents) could hold back young people from taking this route. On the plus side, some businesses did say that their work on the green agenda and technologies related to this was one factor that helped to attract young recruits.

Rural locations, remoteness and the transport barriers that this presents were also raised as a problem by a significant number of businesses. This was seen to restrict the local pool of labour to recruit from either because of travel time, or in some cases because those without a car or the ability to drive simply could not get to them. This is a particular problem for recruiting graduates and young people, many of whom do not drive or have a car, in part linked to the high costs of driving lessons and insurance. Even where public transport options do exist, the infrequency or timing of these can mean that they are of little help in accessing workplaces. An illustration of the impact of transport and locational issues is one business who had wanted to expand in North Yorkshire. It described how it had been unable to attract the employees to allow this, and instead opened its new Research and Development centre in Leeds.

Finally, one different issue in terms of recruitment and training was uncertainty about which technologies skills are required for:

"The challenge is the gaps in skills you don't know you need. Without a specialist in place it is hard to know what else is possible, but you don't bring a specialist in unless you know about that opportunity in the first place."

The business in question gave areas of AI and data that they were not so active in as areas where this paradox might come into play. It could well apply for many other businesses and 4IR technology areas too, including some of those who judge that they are not missing out on opportunities.

3.3.2 Approaches to solving recruitment challenges and training existing staff

Businesses were asked about how they were addressing their 4IR related skills needs, whether through recruitment or training and upskilling of existing staff. This revealed an interesting range of approaches, although in practice these were usually not differentiated from broader training and recruitment activity in the business.

In terms of recruitment, businesses most instinctively talked about how they were seeking to recruit young people into the business, such as recent graduates or apprentices. Section 4.2 covers this and discusses how businesses have engaged with universities, FE colleges and training providers, including around recruitment.

Generally, employers did not report other work-experience focused routes for recruitment, with the exception of one business who had taken on a young person via the Kickstart[21] programme and was happy with the outcome. This was one example of businesses looking to different routes than previously to recruit talent. Another was a business that has recruited engineers from companies who have closed down or downsized elsewhere in the UK, for example in the automotive industry, and found this to be a fruitful way to recruit skilled employees, including engineers with skills in automation. More widely there were examples of businesses using the online and hybrid working models as a way of widening where their employees are recruited – and can work – from. Hence, some are looking across the UK or internationally, based on the fact that employees do not need to be in the workplace for much of the time they are working.

As has already been discussed, many businesses are working to train or further upskill some of their existing employees in using 4IR technologies, such as robotics or cloud computing systems. One major institution reported that *"90% of skills development is in-house"* (once it had attracted highly skilled recruits in the first place), while others noted that one person in the business was in a lead role in learning about how to apply a new system or technology and would then pass on this knowledge to others. Other companies reported using 4IR suppliers to train them in how to use their technology as part of the deal when they bought them or reported buying in support from major consultancies, or sometimes universities, to build their expertise.

3.4 Wider barriers to uptake by 4IR user businesses

Besides barriers that are specifically about skills and understanding, businesses also highlighted a range of other factors that limited or prevented uptake of 4IR technology. Whilst these are not the focus of this report, it is helpful to be aware of them as part of a potentially wider and rounded approach to supporting uptake in businesses, as in some cases skills interventions on their own

[21] Kickstart is a Government scheme that provides funding to employers to create jobs for 16 to 24 year olds on Universal Credit https://www.gov.uk/government/collections/kickstart-scheme

may not be enough to facilitate adoption of 4IR technologies. The range of barriers identified by businesses can be summarised as:

- **Appropriateness, scale and specialisation** – engineering and manufacturing businesses, especially SMEs, often said that they produce nice and tailored products with relatively small-scale production runs. Sometimes this can mean delivering hundreds of different products. These businesses explained that this limits the potential of automation and robotics, which is better suited to large scale production of similar products. Other businesses felt that certain technologies are not relevant to their operations. For example, nanotechnology has potential for some products but not others, while additive manufacturing can be more expensive and slower than traditional methods for some products.

- **Cost, risk and irreversibility** – introducing new 4IR technologies, such as automation, robotics and new production technologies have high entry level costs and can mean multi-million pound investments, and once these are in place it is hard to revert back to the previous models (e.g. if machinery or staff have been replaced). The same principle can apply for shifts to cloud-based systems. Hence, businesses need the funds to invest, a high degree of certainty that it is going to work and pay dividends, and often some appetite for risk: *"you don't do it unless you're definite as there's no going back once you're committed."* There is also a simple question of easy short-term solutions versus more complex and costly tech ones with longer term benefits. As one interviewee put it: *"it costs £80k for a robotic arm but I can buy six lathes for that, which is what I need now."*

- **Regulation, certification and caution** – some industries and products involve detailed certification requirements for products, and without these they may not be allowed onto the market or be able to offer warranties. In some examples, using new technologies and processes would mean losing certification. This is a major problem as *"tech moves fast but changes in regulation and standards are very slow."* Other industries (e.g. oil and gas) were noted as being cautious and conservative in use of some technologies because of catastrophic impacts if something goes wrong; this previously held back use of Wi-Fi on rigs for example.

- **Customer demand and timing** – while the tech may be there, market demand is not always high enough to warrant its use – for example building Internet of Things sensors into products to allow functionality that customers are not yet willing to pay a premium for. Other examples include difficulties for exporters, where some markets may be moving from 4G to 5G, but others are still using 3G, meaning they need to keep products that can be used by all or produce multiple products at greater expense.

- **Culture and digital aversion** – a minority of businesses noted cultural factors that may hold back change, for example related to some engineers being sceptical about digital technology. One interviewee who had experience of working with many companies observed that *"there is an element of fear around the digitisation of certain things"* and that some struggle with the idea of the cloud and where information is stored.

- **Lack of local collaborators** – certain businesses would like to be able to collaborate with others on 4IR technologies, for example around joint use of or sharing learning around technologies such as additive manufacturing and nanotechnology. Currently they perceive there to be little collaboration of this sort and not many high-tech companies and are unaware of who they might make links to.

- **Overstated benefits and reliability** – even those who are applying new tech in many areas, can be sceptical about the business case for others, and are sceptical about whether what is promised at the outset will be delivered in practice. Big data systems are a case in point, where one business pointed to others experiencing spiralling costs and time overruns in moving to such systems in their sector and that *"they all start with great intentions, but most have underwhelmed in reality."* One 4IR expert also noted the dangers of overreliance on technologies such as cloud systems and the importance of back-ups in the event of failure.

3.5 Specific issues in food and farming

It proved harder than anticipated to secure engagement for this research with representatives from the food and farming sectors. Despite that, the conversations that we did have, including with two land-based FE colleges, provided valuable insights that are noted here (and in section 4.2).

Technology and its innovation and advances are fundamental to these sectors. For farming alone, it sits at the heart of the challenge to supply safe and quality food for a growing population, whilst addressing pressures such as a reducing supply of available land; the effects of climate change; animal welfare standards; environmental protection and the climate emergency; and adapting to a post-Brexit agricultural context.

Digital technology can underpin responses to many of these challenges - GPS trackers, automated vehicles, crop planters, fertilising systems, and weather monitoring are just a few examples where the pace of change has been significant and rapid. It is also fundamental to precision farming, which from a livestock perspective alone encompasses the full use of electronic and automated tools to manage and monitor livestock in order to improve their production/reproduction, health and welfare, and impact on the environment. Modern farms as such produce significant amounts of data, with the industry now being *"as much about data as digging."*[22]

With that context in mind, we heard of a number of challenges to driving further adoption of advanced technology in the farming sector. Development of skills that can keep pace with technological advances is a key issue and one that will be hard to overcome given the broad range of new skills required, from electrical engineering to troubleshoot and hardwire systems to data analysis to translate insights into value. Training people in these technologies and how to get the best out of them is very complex and can be overwhelming, especially where farmers may have low levels of basic skills. It demands that the training is good and there are questions as to where farmers can to access this training other than from technology suppliers. This in itself raises issues of trust and risks that *"farmers get sold stuff they think they need but don't understand it."* This issue was seen to be compounded by a large generational gap between older and younger workers in farming in relation to understanding, acceptance and willingness to learn and apply advanced technologies. Extending that line of thinking, more younger people might be attracted to work in farming if they had greater awareness or different perceptions of the role of advanced technologies in the sector and the opportunities these afford for career development.

We also heard that production of vast amounts of data is "all well and good", but itself presents challenges. Farm data is very diverse and is typically collated across multiple platforms that require farmers to carry out multiple entries of data. There is then a skills deficit in farmers knowing how to amalgamate, process and interpret data in a way that is beneficial to their business. Without this,

[22] https://www.weforum.org/agenda/2021/06/farming-data-new-agricultural-job-skills/

they are unable to see the value of investing in such systems or in developing their own skills to best effect. As one interviewee put it *"you have got to really want to do it if you are a very time poor farmer…and therefore many don't."* This presents a real barrier to adoption and there are substantial opportunities for helping the industry to tackle this issue that are both technology and skill based.

"There is a big data race, but people don't know why or what for."

3.6 Skills issues for 4IR technology suppliers

We interviewed five companies who supplied 4IR technologies or expertise around them to others as their core business. These had a range of specialisms, including automation and robotics, embedded software, data focused precision agriculture applications, cloud based analytical planning platforms and development of an AI focused health mobile app. The skills issues discussed for 4IR suppliers in this section inevitably reflect the particular specialisms of these businesses rather than providing a full and even spread across suppliers of all 4IR technologies. This should be borne in mind when considering the specific points raised. However, many of the findings are also more general in nature and have wider applicability.

3.6.1 The type of skills that are relied upon in 4IR supplier businesses

The businesses we interviewed described a range of technical skills, roles and areas of expertise they needed, both specific and more general in nature. The main specific areas they brought out in this respect are:

- Computer scientists and technical computing skills
- Coding/software skills
- Specific embedded software and firmware skills
- Electrical engineers
- General analytical, logic and mathematical skills
- Mechanical engineers

Naturally, the specifics in question varied with the type of business. For example, the company specialising in automation and robotics noted mechanical and electronical engineering skills as well as software, computing and logic skills. Others on the data and cloud-based systems side stressed computer scientists and coding skills, while the embedded software business required a combination of computer scientists and electrical engineering skills, plus quite specific and distinct embedded software skills.

Review of national/international literature can add to this picture. For example, in terms of automation, articles[23] point to key skills including scripting, collaboration, source-code management, Kubernetes (a system for automating software deployment), security, testing, observability, monitoring, and network awareness.

Previous research on digital skills[24] in Y&NY also covered the skills needs of digital sector companies and concluded that these include cloud technologies and platforms; software

[23] https://www.google.com/search?q=what+is+kubernetes&rlz=1C1CHZN_enGB967GB967&oq=what+is+Kubernetes&aqs=chrome.0.0i131i433i512j0i512l9.5648j0j15&sourceid=chrome&ie=UTF-8
[24] https://www.ynylep.com/Portals/0/adam/Stories/OhqqpV3Rg0aL68WCU08pNA/Body/YNY%20LC&CE%20Skills%20report.%20%20Publication.%20Feb%2021.pdf

development, coding and testing; web design and development; cyber security; data analytics and visualisation; technical architecture; user experience and interface design; AI; video conferencing; broadband and 5G; internet of things; robotics; and project management.

Across the business we interviewed, all but one stressed that they need a combination of technical 4IR skills and other skills sets. Most frequently, these were about ability to practically apply skills in a work setting and industry understanding, such as a having a combination of IT and business skills for roles around introducing analytical planning systems, or coders who understand industry. As one business put it in relation to precision agriculture:

"You can get clever programmers, but they don't understand agriculture and its challenges."

Often these discussions revolved around the need for those coming out of education, most typically graduates, to be able to apply academic skills in industry, and they echo sentiments expressed by businesses about use of technology (see 2.1 to 2.3).

This narrative is backed by research by wbs[25] which put 'practical application' as number one in its list of the top ten skills required for the fourth industrial revolution. This argues that *"tech firms are looking for workers who can apply the skills they have learned…for example, they want to see a mobile app created by an applicant rather than a certificate saying they have done the course."*

Related to practical application, the 4IR supplier businesses we interviewed also talked about the importance of the ability to learn (and hence keep track as new technologies emerge and develop) and about aptitude and attitude. There were not seen as replacing technical skills, but as crucial elements they relied on to make the most of those skills in their business. For example:

"We need people who are creative, practical and organisationally dogmatic."

"Our business needs people with aptitude in terms of rigour, tenacity and enthusiasm more than just a good qualification, and with the ability to keep on learning in the job and staying at the forefront."

Finally, one cited the importance of good English writing skills, which was important for writing clear and concise guidance documents for their clients, as doing this badly would communicate a lack of competence to customers: *"You wouldn't buy expensive, specialist equipment from somebody who can't write a sentence!"*

3.6.2 4IR supplier business skills gaps

4IR supplier businesses confirmed that it is hard to recruit people with the specific technical skill sets that are important to them, and to find people who have both these technical skills and the wider skills and aptitudes they seek. This agrees with the findings of digital sector research[26] by global tech recruitment firm, Cloud Assembly, which found that 94% of tech employers believe that there is an industry-wide skills shortage.

The most commonly cited specific gap where it is hard to recruit was software engineers, as well as other related IT roles such as coders (including for embedded software/firmware) and software designers. One 4IR supplier businesses noted that it had wanted to expand its York office but was

[25] https://www.wbs.ac.uk/news/the-10-skills-needed-for-the-fourth-industrial-revolution/
[26] https://www.businesswire.com/news/home/20210622005522/en/The-UK-is-Heading-Towards-a-Digital-Skills-Shortage-Disaster-According-to-Tech-Recruitment-Specialists-Cloud-Assembly

forced to open in London instead because of a shortage of software engineers and system/product designers. Other specific areas of shortages cited included well qualified electrical engineers, and more people who can manage and interpret data.

Besides the company opening a London office instead of expanding in York (and a 4IR user opening a Research and Development office in Leeds instead of North Yorkshire because of recruitment challenges – see 3.3.1) we also noted instances of national and international recruitment facilitated by remote working. For example, one company which recruited around 40 new employees (driven by winning a new contract for embedded software for autonomous vehicles) said it had found a mixture of local people, those seeking to return to York, and others who would remain based in locations from the North East to the south coast and mostly work from home. They said that *"our recruitment pool has widened massively"* as a result. This trend towards distant recruitment, facilitated by home or hybrid working, is double-edged for Y&NY. There are clearly advantages in enabling companies to remain and expand in the region, but drawbacks in terms of fewer local people accessing skilled jobs and less money circulating locally as a result.

4. The role of Higher and Further Education

4.1 Position and perspectives in higher and further education

We spoke to four educational institutions as part of our research – the University of York,[27] Scarborough UTC, [28] Askham Bryan College[29] and Bishop Burton College.[30]

4.1.1 Existing provision

We asked each institution to describe the nature of their provision around the three technology groupings we have used throughout this study.

Automation, robotics, artificial intelligence and machine learning

The University of York is very active in this area, including through the York Robotics Laboratory[31] – a purpose built state-of-the-art research facility for robotics design, construction, research and teaching and a joint venture between the university's Departments of Computer Science and Electronic Engineering. It provides undergraduate and masters courses, including MEng (Hons) Robotic Engineering and a Masters in Computer Science with AI. The university is also home to the Institute for Safe Autonomy where experts are delivering a training and education programme to enable industry, regulators and others to develop the expertise necessary to ensure that robotics and autonomous systems are brought safely to market and into use. There is also expertise and involvement in networks linking AI with the Creative and Digital sectors – linked to the Screen Industries Growth Network and XR Stories – based on immersive and interactive storytelling.

Engineering is one of three specialisms at Scarborough UTC, and whilst the courses are designed to be broad in their coverage, content focused on technology progressively grows as students move up through the programme. This covers engineering design, manufacture and systems control. Good partnerships with businesses allow these technologies to be taught in a real-world context.

From a land based perspective, there has been a good deal of investment in equipment via the Yorkshire and Humber Institute of Technology[32] (YHIoT) including at Bishop Burton College in autonomous/robot tractors that are being integrated into the college's farming systems and teaching resources. These are completely autonomous vehicles that combine data and precision farming, for example in precise positioning of fertiliser or seeds. We did hear, however, that although these vehicles exist in agriculture and there is interest in their use, take up so far is quite low.

Advanced digital technologies and data

The University of York offers a significant number of courses in this field, e.g. computing and computing with data analytics and attracts students in high volumes. Quantum computing, cloud and big data are picked up on courses at undergraduate and masters level and the university is looking at expanding its provision in these areas.

Scarborough UTC has a specialism in cyber security that ensures students learn all underpinning theories of the internet, data and its manipulation and software programming. Computer Science is offered at GCSE and A Level, as well as a BTEC in ICT and Computing. There is specific

[27] https://www.york.ac.uk/
[28] https://www.scarboroughutc.co.uk/
[29] https://www.askham-bryan.ac.uk/
[30] https://www.bishopburton.ac.uk/
[31] https://www.york.ac.uk/robot-lab/
[32] http://yhiot.ac.uk/

curriculum enrichment on cyber security, and this is backed by a strong local partnership with GCHQ,[33] with representatives regularly visiting the UTC to run information sessions and to set projects and challenges for the students.

Digital technologies are increasingly being built into the offer at Askham Bryan College, including investment in an Agri-Tech Innovation Centre and a Digital Farm; and £1.7m invested via the YHIoT to provide precision equipment specifically for rearing livestock. Full and foundation degrees, e.g. in Precision Livestock, as well as bite size courses, are introducing these technologies and helping people explore their potential uses to improve monitoring, resource management and productivity.

Bishop Burton College's offer in Precision Crop Technology, due to be launched in 2022, is focused on teaching students about advanced technologies that optimise yield and environmental protection. Teaching is based on the use of information technology and a wide range of applications such as GPS guidance, control systems, sensors, robotics, drones, autonomous vehicles, soil sampling, and satellite technology allowing real-time management of crops and fields. Its Precision Agriculture programme operates at Levels 4 and 5 and focuses on the use and application of farm data.

Other advanced technologies

When asked, the institutions we spoke to leant towards describing their provision in green technologies. For the University of York that includes significant expertise and an expanding offer via the York Environmental Sustainability Institute[34] that will facilitate and deliver world-class interdisciplinary research on environmental sustainability for the research community, industry and policymakers. Scarborough UTC embeds content on this into their engineering courses, typically looking at mechanical and product design and material selection and use.

There has been college investment in green technologies linked to precision farming, with Bishop Burton looking at a range of renewable energy sources and their application in horticulture including, for example, small scale anaerobic digestors that can be put alongside food outlets to turn food waste into gas for cooking and use in fertilisers. The college has developed Level 3 provision in Green Energy, focusing on agricultural and horticultural industries as well as food and food manufacturers, given the link to small scale anaerobic digestion.

4.1.2 Student demand

The University of York expressed healthy levels of demand from students for its courses in these areas and expects that provision will continue to expand as a result. The picture was more mixed for the other institutions we spoke to. Scarborough UTC is seeing numbers grow thanks to a strong curriculum, a good reputation with businesses and parents, and students achieving good onward destinations. However, their courses are not full and the view is that they need more people to recognise the benefits of the UTC model, and the opportunities that can flow from following STEM subjects – *"the destinations of our students into HE and quality apprenticeships including at degree level speak for themselves - we have been transformational for the young people that come here."*

The two land-based colleges told a similar story of demand being fairly low but growing moderately and tending still to be from within farming families and communities. It appears that there remains work to do to shift perceptions of farming away from the traditional to include these areas of technology in order to widen appeal:

[33] Government Communications Headquarters based in Scarborough https://www.gchq.gov.uk/
[34] https://www.york.ac.uk/yesi/

"There is a perception that agriculture is the little red tractor, but actually the future opportunities are incredible."

4.1.3 Business engagement from an educational institution perspective

All of the institutions we spoke to reported having links to business in some form; but equally all were aware that there was scope to do more.

The University of York is engaging with businesses on AI, robotics and automation via partnerships with companies which tend to be large national companies or smaller ones in the region (as they were not aware of many large ones locally). Action has included co-funded joint research, in-kind partnerships and data sharing, much of which is innovation and R&D focused. There have also been small scale partnerships on skills, and there is appetite to do this on a larger and repeatable scale. There are only a small number of student placements each year – typically between 80 and 100 from over 10,000 students. Courses tend not to have placements built into them, but all students are given the option of having a placement year and relevant support should they wish to do so (although often they do not if their friends and peers have opted not to). Increasing commercial links and the revenue that flows from this is central to the university's forward plan, and a focus on advanced technologies is key within this, for example by offering more bespoke training. Difficulty in identifying relevant businesses and making them aware of the university's offer has hindered this in the past, as has the cost of setting up new courses.

The UTC model is built on strong partnership with business and hence very good links are being made with a good number of *"very committed"* employers who readily get involved in course design and delivery. By its nature, this allows students to see how technologies are being applied in practice. The UTC also more broadly runs a two-year sixth form Career Development Programme, where each student is mentored by one of the UTC's partner businesses. This helps build a meaningful relationship, which may ultimately develop into a job, and is of far greater depth than standard one-week work experience offers. There are limits to how far this can go, however, in a local context where businesses are mostly small and meaningful engagement with education is a big commitment that usually falls on one member of staff.

Engagement with business from a land-based college perspective is and needs to be two-fold. Firstly, there is engagement with farms as businesses. Colleges are engaging, however, there is a big divide between large, profit-motivated farmers who are more likely to seek out and use new technologies (where these technologies have hence become the norm); and smaller, family run traditional farms who can struggle to know what they need and to keep pace with technological change. For the latter, it is far harder to present training offers to farmers who are typically exceptionally busy and cannot take time out. Nevertheless, Askham Bryan College was optimistic that farm and land-based businesses can adapt and that demand will grow as there is a clear link between the skills needed to use the tech and understand what it is telling them in terms of data, and the ability to increase farm productivity and animal welfare.

This latter point makes the second area of engagement - with agricultural technology equipment suppliers – even more critical. Technology suppliers are often relied on to train customers in the use of their technology, but often are not equipped with the skill set to do that to best effect. Colleges can help bridge this gap, as well as bring some neutrality in terms of helping farmers not to feel as if they are *"being sold to."* Askham Bryan has established Technology Advisory Boards to help develop their curriculum in a way that can help

4.2 Awareness and connections from a business perspective

4.2.1 Existing engagement with education

All but two of the 4IR user businesses we interviewed had existing links of one sort or another with educational institutions or (in one instance) independent training providers around their skills needs, as well as additional links around innovation and expertise in some instances. However, only a few of these appeared to be particularly well developed and extensive. Examples of the links described include:

- Three businesses noted links to the University of York – although only one had very strong and current links around skills (via a large scale PhD placement programme); while one used to have links with the university that had faded away; and for another the connection was mainly about R&D.

- Two businesses talked about skills links between businesses and education in Scarborough focused on cyber security. These mainly involved Scarborough TEC and its connections to companies such as Anglo American (see Annex for case study) and GCHQ, but one business also noted (less strong) links to Scarborough UTC and Coventry University[35] in Scarborough.

- A few businesses talk about links to universities further afield, notably the University of Sheffield[36] and the University of Newcastle,[37] although for one business these links were more about consultancy than education and skills.

Individual instances of other connections were also noted, for example *"bits and pieces*" with Harrogate College[38] and Leeds College of Building,[39] and one business who used Derwent Training for apprenticeships.

Four of the five 4IR suppliers we interviewed had connections with FE Colleges or more usually universities of varying degrees and types. Two of these were with the University of York and its Department of Computer Science which is seen as a major asset. One company has an intern programme with the university, and another has a major intake of (20+) students on industrial placements from the university each year. They have found this valuable as the partnership builds the vial mix of theoretical understanding and practical experience required, and leads to many of them coming back as employees when they graduate:

"They get insight into the job and what they need to focus on in their final year studies and we get to interview them for a year."

Other businesses had less well-developed FE/HE links, but one reported that they had some links with York St. John University[40] and Leeds Beckett University[41] and had recently established a helpful connection with Leeds Trinity University[42] through the Skills for Growth Programme[43] that operates in Leeds City Region. Another noted Askham Bryan College as a good resource, but that

[35] https://www.coventry.ac.uk/cus/
[36] https://www.sheffield.ac.uk/
[37] https://www.ncl.ac.uk/
[38] https://harrogate-college.ac.uk/
[39] https://www.lcb.ac.uk/
[40] https://www.yorksj.ac.uk/
[41] https://www.leedsbeckett.ac.uk/
[42] https://www.leedstrinity.ac.uk/
[43] https://www.the-lep.com/business-support/skills-and-training/skills-for-growth/

fixed term times, set lessons and a lack of teaching on the tech side restricted how far it could support farmers in building their skills and ability to use tech.

Recruitment of graduates from universities tended to be the norm across both 4IR users and suppliers, and businesses tend to associate high level and technical roles as needing a degree in a relevant topic as a minimum qualification. Reflecting this, some businesses (notably, larger ones) have established graduate recruitment programmes. However, as has been noted, we also uncovered a number of well-developed undergraduate placement programmes, and in one case a programme of PhD placements. These were seen as highly effective ways of building relationships between students and businesses, and in attracting a good number of them as future recruits. As well as bringing skilled people into businesses, this model is seen as having advantages in terms of moulding a student to the business and giving them practical, workplace experience, and in supporting good retention rates as those recruited already know the business and whether it is somewhere they would like to work.

A significant minority of employers had established (sometimes very significant scale) apprentice programmes, linked in some cases to a realisation that *"long term, growing and investing in your own talent is the way forward."* Where these have been put in place, businesses appear to be happy with them. A number of other employers did not have apprenticeship schemes but appeared open to the idea of them when probed. With the right communication, nudges and help to make this easy, this suggests that an additional cohort of businesses, certainly in engineering, could take on apprentices in the future.

4.2.2 Perceived issues, challenges and barriers to further engagement

Businesses suggested a number of issues and challenges in engaging with educational institutions, and the same points tended to emerge for both 4IR suppliers and users.

A spread of businesses said that it needed to be easier for businesses to find out about what the HE and FE offer is in terms of skills, courses and potential future placement students and recruits and then to collaborate. Even those that were seeking to make a connection had found this difficult, often coming across something by chance rather than by design.

"It's never as easy as it sounds to get the right person and make the right link."

One business noted the Leeds City Region Skills for Growth Programme as a good model in this respect (which covers parts of North Yorkshire), particularly as it has a focus on helping businesses to find the best HE or FE institution to meet their needs. Another suggested establishing a single, easily accessible platform that collates and communicates information about the business offer in each institution across York and North Yorkshire.

Businesses also re-emphasised the need for universities to further develop hands-on experience rather than just theoretical understanding:

"Universities are driven by academics and what we need are practical skills."

"Students come out of university and are raw, they need practical skills to apply what they have learnt. There is a gap between analytical skills and the practical world."

There was a view that a perception shift is still needed in terms of apprenticeships as a solution to this blended academic and practical approach, especially when done at degree level. This counters issues with degree level courses being too generic or going out of date too quickly.

Others noted gaps in courses where they would like to new or expanded provision (e.g. Data Science, Computer Science) or where new content in areas like robotics, automation and new green technologies needs to be integrated into existing courses. For example one business noted that there was not an apprenticeship that included a robotics module, and others made more general points about the need to keep courses up to speed with new and emerging technologies:

"A lot of people come out of courses with traditional and out of date skills, for example not knowing about green technologies like solar and heat pumps."

"There are not enough data science courses – this is a missed opportunity, and the gap is growing – everything coalesces around data."

The challenge for colleges and universities in keeping pace with fast moving and expensive technologies was noted as a challenge more widely with partnership with industry seen as important to help address that.

Finally, the need to make business demand clear to education, and to promote tech and STEM subjects to young people from school onwards was seen as vital to secure the numbers needed becoming qualified in relevant areas. Diversity was a big issue in this respect too. One business reflected that *"the field is approximately 80% male"* and stressed a desire to see energy put into getting girls into STEM, which needed *"a unified approach, and to start in school – by the time you get to uni it is too late."* They envisaged that schools, FE and HE would have a big role to play in this as part of a consistent approach.

4.3 Potential solutions

A range of potential solutions to tackling skills gaps associated with uptake and application of advanced technologies emerged from our discussions with businesses and with education. These are incorporated into our recommendations in section 5.2, but also considered more broadly here.

It appears that there is a strong case for expanding provision of HE courses that are closely related to skills shortage areas, notably in computer science and data analysis. Equally, it is important to make sure that existing provision is widely promoted to business, and to have mechanisms in place to ensure that they can easily find out what is available and how to access it. Similarly, there is a case for greater collaborative learning between business and academia, with work placements at the heart of this to better blend academic and practical learning. Businesses also expressed an appetite to explore how apprenticeships (especially at degree level) can be used in this regard.

It is clear, however, that solutions to skills needs are not purely a matter of providing more advanced technology focused courses. There is also a strong case for better integration of 4IR content into relevant existing HE and FE courses, e.g. inclusion of modules on robotics within engineering courses and apprenticeships in a way that helps foster greater technical skills and awareness within the talent pipeline. Aligned to this, there remains a need for greater promotion of tech and STEM in education, including a consistent focus on engaging more girls in STEM subjects as a route to address diversity challenges that many advanced tech businesses face. It is critical to start early by

working with schools to deliver the curriculum in a way that supports technical education; as well as to demonstrate the breadth of career opportunities that are available.

There is also a need to align academia and business in respect to equipment and demonstrating when, why and how advanced technologies can be used. Sometimes it will be a large business that has equipment that students can see and use; at other times, particularly for SMEs, it will be education institutions who can house and demonstrate equipment. The latter is, for example, the case in colleges that have benefited from YHIoT capital investment, and there is a case for far greater promotion of these offers backed by capacity to translate technical expertise into practical ways forward for businesses. This can also be helped by provision of shorter and flexible training courses for businesses, which are easier for businesses to utilise in upskilling their workforces.

5. Conclusions and Recommendations

The conclusions from our research include assessment of the current position, barriers to progress, solutions to overcoming these, and recommendations for action where appropriate. They are cognisant of findings from other research, such as on digital skills in the region, which are also relevant to formulating responses that are pertinent to businesses applying advanced digital technologies.

It should be noted that as the sample of businesses this research is based on had a focus on medium and large sized engineering and manufacturing businesses; the conclusions will reflect the position for this group rather than necessarily businesses overall.

5.1 Conclusions

Current and future application of 4IR technologies by businesses

- Larger and international businesses and are often forward looking and active in a wide range of advanced technologies including those technologies relating to data and computing, automation, robotics and advanced production. A small minority are at the forefront of their industries, others know much about what can be done in principle and are moving towards practical application.

- SMEs may use advanced technologies in a few areas that are core to what they do, but rarely have specialists to cover wider areas, and knowledge and application is more limited. In part, this is because they often *"don't know what they don't know"* which limits exploration and application of new/advanced technologies. It is also due to the nature of their business, for example if they do not produce in volumes required to offset the scale of investment required, or their products are too niche or specialist.

- Engineering and manufacturing businesses tend to use 4IR technologies to help create or produce something physical, for example via automation and robotics, or in some cases the use of innovative new materials. For some, the focus of this is on using robots to carry out repetitive and mundane processes which enables skilled employees to focus instead on high value tasks.

- There is some use of additive manufacturing; however, this is often small scale and only used for developing specific products and prototypes, because it can be slow and expensive to use at scale for some businesses.

- Application of advanced digital technologies is more common and clustered around cloud computing and data, and the vast majority see future application of these technologies as continuing to grow. Data is seen as key to driving efficiency. However, take up of new technologies that support businesses to extract and analyse data to its full potential is variable, and the skills available to do so are in short supply.

- Digital technology is intrinsic to developments in agri-tech e.g. in GPS trackers, automated vehicles, weather monitoring and precision agriculture and livestock farming. As a result, farms now produce significant amounts of data. However, many farmers do not know how to amalgamate, process and interpret this data in a way that is beneficial to their business.

- Although not widespread in the businesses we interviewed, there is some evidence of there being a culture of scepticism towards advanced data and IT technologies within some traditional businesses and amongst some of their engineers. In farming, this exists as a generational gap between older and younger workers in relation to understanding and willingness to learn and apply advanced technologies. More younger people might be attracted to work in farming if they had greater awareness of the role advanced technologies play and the opportunities these afford for career development.

- A good deal of highly advanced digital technology e.g. quantum computing, remains confined to the world of academia and major tech companies such as Google. It has not yet become more mainstream in the way that other digital technologies such as Cloud computing have.

- For many larger businesses, the green agenda is a central driver in the pursuit of new technology and solutions. Examples include collaboration with universities to develop new material combinations to improve housing energy efficiency; and conversion to a fully hydrogen powered fleet of mining vehicles.

- The pace of change in tech is extremely fast and this makes it hard for businesses and educational institutions alike to keep up. Furthermore, timing is crucial. Some technologies are seen as being about *"tomorrow's problems"* and hence require forward looking businesses with awareness of future trends and technologies, and who have some appetite for risk, to implement them early.

- Other bodies are likely to be active in this space nationally e.g. AMRC, TWI and Make UK. There is scope to consider how businesses and institutions in York and North Yorkshire can best collaborate with and gain maximum benefit from these bodies.

Current attitudes, understanding, skills and expertise

- Many businesses see skills levels in this area as important, sometimes vitally so. Some already have or are developing relevant skills within their workforce, others access them mainly through external suppliers and consultants, and sometimes through other parts of the company (if they are a branch within a larger business) or universities.

- Businesses usually believe that they have reasonable or good awareness and understanding around the 4IR technologies which they feel are most relevant to themselves. Levels of understanding are typically viewed as sufficient rather than specialist in nature. Most businesses do not feel they are missing out on opportunities through lack of skills but do see that they are on a learning curve and would like to enhance their skills and understanding. A minority of businesses are more expert, usually larger and international ones.

  In SMEs, awareness and understanding of 4IR technologies and their opportunities is often down to one or a few individuals who are keen and interested in this area more than trained experts, for example a director or engineer. Others see that it is mainly an area for younger employees to lead on. These responses are pragmatic and can utilise and build workforce skills but can be questioned in terms of the scale and reliability of expertise and whether or not this is an appropriate long term solution.

- Within manufacturing and engineering businesses, there is typically more confidence about their skills and understanding in areas such as robotics and automation than in digital and data focused technologies such as Cloud computing and cyber security, where reliance on external suppliers and specialists is greater.

- While many businesses feel they have enough awareness of 4IR technologies and their opportunities, it is hard to know how far this perception is sufficiently robust, or whether it may be misplaced in some instances, especially given the range of 4IR technologies and the pace at which they are developing.

Skills needs, issues and shortages

- More than two thirds of relevant companies face challenges in recruiting to highly skilled technical roles. These range from surmountable to severe in terms of how far and easily challenges can be overcome, and their impact on a business. People with the right expertise are highly sought after in a very competitive, global labour market with major skills shortages.

- Examples of hard to recruit roles within businesses using 4IR technologies include software engineers, robotics engineers, data scientists and data analysts, as well as roles in Cloud computing, new areas of green technology, and high level biological/chemical expertise.

- Roles and specialisms where 4IR supplier businesses face skills and recruitment challenges include computer scientists and technical computing skills, coding/software skills, specific embedded software skills, electrical engineers and mechanical engineers, as well as individuals with strong analytical, logic and mathematical skills who can be moulded to specific roles.

- Recruitment is made more complex as businesses are sometimes seeking individuals with multiple skills sets – for example engineers who also have 4IR tech skills such as in automation, robotics and digital fields. Given existing skills shortages for engineers, there is a risk that these may be overshadow the 4IR skills element for businesses where engineering skills are the priority if a recruit with both of the skills sets sought cannot be found.

- Businesses using and supplying 4IR technologies seek aptitude and capability as well as technical skills. They are looking for people who are creative, practical, can self-learn and are able to apply knowledge in a business setting and often say that these are lacking, notably in relation to young people and recent graduates,

- Recruitment challenges are greater for businesses in remote locations seeking to recruit young people, many of whom cannot drive. Solutions focused on transport and access may be appropriate in these cases.

- We found examples of businesses with a Y&NY base or HQ that have expanded or created new offices elsewhere because they cannot access the skilled labour they need locally in Y&NY. Additionally, shifts to greater online or hybrid working are widening the geography from which companies are recruiting from for specialist roles – across the UK and sometimes internationally.

- From a farming perspective, advances in technology demand skills in digital technology, analysis of data to develop insights, and electrical engineering (as many advances need to be

hardwired). However, there are real barriers to engaging and then delivering training to time-poor farmers who are often reluctant to accept the role advanced technologies can play.

Connections between businesses and education

- Of the institutions we spoke to, only the University of York is seeing strong and growing demand for advanced technology courses and expects to grow its provision as a result. For others, demand is there but growing more moderately. This correlates with the fact that most businesses we spoke to (rightly or not) tended to look towards HE rather than FE for advanced technology skills.

- There are some examples of good business-education collaboration. However, there is also uncertainty and confusion amongst businesses about the range of courses available across institutions, the skills that they can foster in learners, and how to go about finding an institution that best fits with their needs. A single platform that collates this information and then clearly communicates and promotes it would be helpful.

- Educational institutions are keen to develop their links with businesses, however they perceive that opportunities to do this locally are constrained by the relatively limited numbers of businesses of sufficient scale and technological complexity. There is more to explore on how this can be overcome, linked to creating the right environment to support commercialisation of research and spin-offs from university to foster a spirit of advanced technology enterprise and innovation and retain graduate talent.

- Integrating content on advanced technologies such as robotics and new digital technologies into apprenticeships and FE/HE courses is important, so that 4IR tech awareness is mainstreamed.

- Educational institutions need to support learners to develop aptitude, capability and practical experience as well as academic credentials and theoretical understanding. A large increase in the number of undergraduate (and other) placements was seen as a good way to foster this blend of academic and hands-on learning, as placements are valued where they are happening.

- It is unrealistic to expect all advanced technology to be taught via HE and FE curricula. Partnerships between education and businesses are essential in achieving this, not least because the private sector is better able to provide much of the cutting-edge equipment that is needed and that is hard or too costly for education to obtain. Technology suppliers also have a role to play in imparting good quality information and training on how and why to use their equipment to get the most from it.

- Jobs that demand skills in advanced technologies are typically high quality and well paid. Apprenticeships, especially at degree level, will be one way of ensuring the right blend of academic and hands on learning, and there are examples of them working well in Y&NY. This can also mitigate the risk of technology moving at too fast a pace for HE/FE courses to keep up with.

- There continues to be a need to shift perceptions about the attractiveness of STEM subjects and to raise awareness amongst learners of the career opportunities that can be accessed through of studying these subjects. This will be key to tackling diversity issues that feature in advanced technology sectors, and the major deficit in females pursuing STEM based subjects and careers.

Other barriers and issues affecting uptake

- Barriers to greater adoption of advanced technologies include the scale of investment required, high entry costs and the ability to access finance. This is the case for business start-ups as well as for potentially multi-million pound investments by established companies.

- Automation is a long-term shift in the processes of a business and is largely irreversible in nature. Businesses must therefore have a very high degree of certainty that automation is the right solution for them before they are prepared to commit the necessary capital investment. They must also be confident that the technology will not be quickly superseded and hence become obsolete; and be willing to accept a degree of risk.

- Some new products and the technologies they use must be certified before they can be approved for sale or use. This can limit and slow down new developments and application of advanced technology.

- There is a need for caution around the wholesale reliance on new technology which may be fragile or present vulnerabilities in there is no back-up provision, for example if there were a failure with Cloud storage. Others noted that some technological changes, such as movements toward big data and new computing systems can be prone to increasing costs and long delays.

- We uncovered few if any collaborations between different businesses on 4IR technologies, but some businesses did express an interest in exploring such relationships. There may be potential for then to do so gainfully, for example around sharing facilities, equipment or expertise.

5.2 Recommendations and potential ways forward

Education and skills focused recommendations

Recommendation 1: Improve information and awareness in businesses about how educational institutions including universities and FE colleges can help them with 4IR skills needs, expertise and equipment. Solutions may include the use of a shared platform setting out the HE/FE offer, proactive communications, or employing people in brokerage roles that help to connect businesses to provision that best meets their needs. In parallel, improve awareness in relevant HE and FE departments about local businesses activity in this sphere.

Recommendation 2: Encourage expanded provision around the most relevant HE courses to provide more skilled graduates, for example in robotics, computer science, cyber security and data analysis, in order to widen the local talent pool. Use dialogue with business to ensure provision also builds practical application skills and is shaped by demand, including through routes such as Technical Advisory Boards.

Recommendation 3: Integrate 4IR content into relevant HE and FE courses to help foster and widen technical skills and awareness in the future workforce. Examples could include seeding modules on robotics into engineering courses and apprenticeships, as well as content on digital, data and green technologies linked to the net zero agenda.

Recommendation 4: Increase demand from young people to study and seek careers in 4IR related subjects and specialisms that meet business needs. This should include strong IAG that demonstrates the breadth of available career opportunities and greater promotion of tech and STEM in education from early years and have focus on engaging more girls in these subjects to address diversity challenges that many advanced tech businesses face.

Recommendation 5: Work with education institutions to radically increase the number of relevant courses that offer undergraduate (and other) placements in businesses applying 4IR technologies. This is a highly effective model for blending academic and practical learning, building long-term partnerships between education and business, and enhancing future recruitment and retention. The base level is currently low but there is appetite from both sides to do more, and good practice that can be learned from.

Recommendation 6: Promote awareness and uptake of apprenticeship opportunities in this field, including through raising the perceived value of this pathway and highlighting the potential of degree level apprenticeships to build academic and practical skills. Many SMEs may not be fully aware of these opportunities or how to put them in place, so support and encouragement to help businesses make the first move may be needed.

Recommendation 7: Encourage and communicate provision of shorter and flexible training courses for businesses to upskill employees, as there is likely to be greater take up of bite-size or incremental learning that is manageable within tight financial and time constraints.

Wider recommendations

Recommendation 8: Explore the potential to develop a technology diagnostic and opportunities assessment service for SMEs. This could involve using advisers with sufficient understanding of business and the sector in question, and relevant technologies and solutions, to identify opportunities for action and link them to more specialist expertise.

Recommendation 9: Consider the development of a high profile and accessible Centre of Excellence for Advanced Technology, or a network of such hubs with different 4IR specialisms, linked to HE expertise, and connected to the Institute of Technology and relevant provision in FE. This would demonstrate and communicate what is possible in respect to the application of advanced technologies, in a way that can be understood by non-specialists and enable them to connect to experts and suppliers and develop practical ways forward for their business.

Recommendation 10: Continue to use wider business support, innovation and economic development interventions to create the right environment for commercialisation of research and the creation of new businesses and spin-offs from universities. This should include fostering a spirit of collaboration and enterprise, and consideration of how public and private funding mechanisms can support investment in the face of high entry costs. More widely, promote the region's attractive environment and quality of life to help attract and retain high tech businesses and skilled workers, and enhance connectivity to enable those who cannot drive (including many recent graduates) to access jobs in relevant businesses, including in hard to access locations.

Recommendation 11: Capitalise upon business interest in the green/net zero agenda as a driver for innovation and utilisation of advanced technologies and identify and promote such opportunities to a wider range of businesses, especially SMEs.

Recommendation 12: Explore opportunities to help businesses with similar technological interests/opportunities to collaborate and exploit potential synergies, e.g. to share or rent out specialist equipment, to build and share expertise, or to seek joint funding. Routes to do this may include working through innovation networks or business representative bodies (e.g. the Chamber of Commerce or Make UK), hosting knowledge transfer or 'tech meet-up' events or putting businesses in touch with one another where there are existing geographical clusters.

ANNEX: Case studies of application of 4IR technologies

Ryedale Group

The Ryedale Group[44] is a family business that has been based in Kirkbymoorside since 1952. It is an information and a production based business, with lines including sustainable plastic print production and horticultural plant care labels and cards. It has applied new 4IR technologies for both 'hardware' and 'software' elements of the business.

On the **hardware side**, it has developed automated robotic production equipment to replace an entirely manual and routine task that involved cracking bundles of labels out of a stack of sheets. The business had struggled to find people who could do this task, and the new automated process would overcome this problem and reduce the number of staff needed.

As a specialist company, it could not buy an off-the-shelf solution, so it shaped up what it wanted and teamed up with local engineers and software developers to design and build its own solutions, mainly in the print finishing department. Overall, it took around two years to fully develop and implement the project. As it was a great success, the business then went on to buy two more (improved) machines off the back of that first generation 1 prototype and rolled out the process to a wider range of products, one of which was supported by a PAPI grant[45] from the University of York.

The company has been able to train operators to run and maintain the machine, which is a more skilled role, and because the packing task is less physically taxing, a wider range of people are able perform the task. The new technology has made the business much more productive and helped to offset rising labour costs. Additionally, the machines were designed to be as simple as possible and to have a very quick payback period. While the initial drive to innovate through a new machine came from management, once it was in place the operators did a great job of fine tuning the process and helping to develop further generations.

The business has also innovated on the **software side** to enhance workflow using similar principles - keep it simple and use local engineers. This was important as the business is highly seasonal and depends on maintaining a healthy workflow through the business, supported by having the correct information. Just before Covid-19 struck it had moved most of its workflow to the Cloud, which provided a connected pathway through the business from sales, through to design and artwork studio, production and purchasing, the warehouse, and connected to finance. The software purchased to enable this is highly customised and has been further and rapidly developed over time, with the Ryedale Group's own team given flexibility to innovate and add new features.

Ryedale Group has partnered with suppliers to bring in the specialist skills needed to support its use of advanced technologies and is also retraining its own staff to use software rather than pass around emails and spreadsheets. Although, implementing the changes presented some challenges to begin with, the fact that its system is logical and has directly incorporated ideas from teams into their development has helped to overcome any difficulties. The change is seen as having been very successful all in all. An additional benefit has been that going online supports easier staff transfers and/or recruitment from further afield, because working from home or hybrid working is possible.

[44] https://ryedalegroup.com/

[45] PAPI encourages innovation with 40% capital grants of up to £20k to support the development of new products or services and is open to SMEs in York, North Yorkshire and Leeds City Region https://papi.org.uk/

Anglo American

Anglo American[46] is a global mining company, employing close to 100,000 people. The company, headquartered in London, operates primarily in the Southern Hemisphere, mining for metals and materials such as copper, diamonds and iron ore. In February 2020, the company acquired the Woodsmith Project in Whitby, its first and only operation in Europe, where it is building a new mine focused on the world's largest and highest grade polyhalite resource for use in crop nutrition. The mine will extract the material from one mile beneath the surface, then transport it via a 23 mile underground tunnel to Teeside for processing and then global export via local port facilities.

Anglo American's mission is to re-imagine mining to improve people's lives. Their 'Future Smart Mining' approach is central to achieving this. It focuses on precision extraction of metals and minerals via integrated technology and data driven mining methods. This innovation-led approach is helping the company to mine in ways that are safer, more productive and efficient, and more sustainable, helping them to meet their commitment to be carbon neutral by 2040 – ten years ahead of their industry. Innovations include transforming the company's fleet of 500 tonne mining vehicles to become fully automated, remotely operated and hydrogen powered.

Digitisation and data underpin Future Smart Mining. All innovations are fully digitally connected, capturing substantial volumes of smart data that can be analysed to inform decision making and boost efficiency, quality and speed, to drive down cost, and ultimately to boost sustainability. This includes for example data that allows the business to understand exactly how every piece of machinery is operating – from its productivity to whether it is about to breakdown (so that pre-emptive repairs can be made). This transformative shift to digital and data-led operations has required the company to examine its skills needs, including how it can upskill and reskill its existing workforce, as well as build a pipeline of skills for the future.

Cyber security has been identified as a critical area for the business to focus its skills effort on. This recognises three things: a) the volume of data produced in the business each day and the value of it to the company; b) that cyber crime is increasing at an alarming rate globally, with one in four UK companies having experienced a cyber breach; and c) the significant UK shortage in cyber security skills, with 37% of roles deemed 'hard to fill' and 40% of applicants lacking the necessary skills.

In response, Anglo American established its own Cyber Apprenticeship programme based at its North Yorkshire operation. This is a long term investment in growing its own talent pipeline in a way that blends high quality practical and academic learning. From October 2022, it will take on its first cohort of seven apprentices, with a plan for 14 apprentices to be in post concurrently. It is a two-year, Level 4 apprenticeship based on an 80/20 split of on the job and formal learning. As well as their apprenticeship, participants will achieve four industry certification qualifications, experience a range of roles in cyber security, and can aspire to becoming a full time employee on completion.

In addition, the company is a member of Cyber First,[47] the national scheme designed to identify, inspire and nurture a diverse range of talented young people into a cyber security career. Anglo American is going into schools locally to deliver cyber related activity, in its first year reaching 400 children. It is also working with Scarborough Borough Council, GCHQ and Coventry University Scarborough to pool resources and expertise to help turn North Yorkshire into a cyber security hub focused on operational technologies.

[46] https://www.angloamerican.com/
[47] https://www.ncsc.gov.uk/cyberfirst/overview

Glossary

4IR – Fourth Industrial Revolution (also referred to as Industry 4.0 – see below for description)
AI – Artificial Intelligence
AMRC – University of Sheffield Advanced Manufacturing Research Centre
FE – Further Education
HE – Higher Education
IAG – Information, Advice and Guidance
Industry 4.0 – see 4IR
IoT – Internet of Things
LEP – Local Enterprise Partnership
ML – Machine Learning
SME – Small and Medium Enterprise(s)
STEM – Science, Technology, Engineering and Maths
TWI – The Welding Institute
VR – Virtual Reality
YHIoT – Yorkshire and Humber Institute of Technology
Y&NY – York and North Yorkshire

Fourth Industrial Revolution:
The Fourth Industrial Revolution (4IR), also known as Industry 4.0, is the unfolding age of digitalization—from the digitally connected products and services we consume, to advancements in smart cities and factories and increasingly common automation of tasks and services in our homes and at work, has finally come of age (https://www.pwc.com/us/en/library/4ir-ready.html).

The distinction between Automation and Robotics:
Automation is the use of self-operating physical machines, computer software, and other technologies to perform tasks that are usually done by people. This process is designed to automatically follow a predetermined sequence of operations or respond to encoded instructions. Robotics is the design, creation, and use of robots to perform tasks. These are physical robots that substitute for (or replicate) human actions (https://www.workfusion.com/blog/the-difference-between-robotics-and-automation/).

Internet of Things (IoT):
The Internet of Things is the concept of connecting any device (so long as it has an on/off switch) to the Internet and to other connected devices. The IoT is a giant network of connected things and people – all of which collect and share data about the way they are used and about the environment around them (https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/).