Digital skills in context: Working with robots in lower-skilled jobs

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Abstract

Digital skills are increasingly presented as essential for work and labour market inclusion, with fears the low-skilled could be left behind. Lack of clarity about these new skill demands and limited evidence from the workplace have prompted calls to unpack skill requirements in specific sectors and occupations. This article analyses digital skills in relation to wider skills and knowledge required in a job, and examines the influence of the workplace, sector and national institutional context. The study focuses on robotic technologies in lower-skilled jobs, drawing on the experience of food and drink processing operatives, and logistic porters and service workers in public hospitals, in Norway and the UK. The article contributes to the conceptualisation of digital skills, probes country differences, and offers a grounded understanding of the challenges presented for workers in lower-skilled jobs.

Keywords

Digital skills; lower-skilled jobs; UK; Norway; food and drink processing; hospital logistics; robots

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Digital skills are widely seen as increasingly important for life, work and the economy (Berger and Frey 2016, OECD 2019a). Although forecasts of job losses from digitalisation vary enormously (Arntz et al 2016, Frey and Osborne 2017), many agree that changes to digital skills requirements are already happening, and that those unable to cope are at risk of labour market exclusion (EC 2017, Czaja and Urbaniec 2019). Surveys suggest one in ten of the EU labour force have no digital skills and a third lack basic digital skills (DESI 2019:6), with the less qualified, and those aged over 55, faring worse (Martin 2018). Digital 'skills gaps' and 'digital divides' are also seen as damaging for the economy and post-pandemic recovery (HCSTC 2016:3, Curtarelli et al 2017, LWI 2021).

Workers in lower-skilled 'routine' jobs are held to be most vulnerable to automation and more likely to struggle with digital skills (Cedefop 2016, Frey and Osborne 2017). Much of the policy discussion, therefore, is around 'future proofing' the workforce by retraining workers to cope with task changes or equip them for new jobs that are assumed to require digital competency. In the UK, policymakers refer to a 'digital skills crisis' (HCSTC 2016), but similar concerns around digital skills shortages and gaps are reflected in international reports (e.g. OECD 2016, EC 2021a). However, problems in defining digital skills, coupled with a paucity of evidence from the workplace, make it difficult to assess how requirements are actually changing (Brown et al 2018, Keep 2021). This raises questions as to whether terms like 'crisis' and claims of escalating skills gaps may overplay the complexity of some of these new skill demands. The aim of this article is to critically explore the conceptualisation and use of digital skills, with a specific focus on workers in lower-skilled jobs.

Digital skills are an amorphous concept, spanning everything from using a computer mouse and web browsing to advanced programming and 'blockchain' development (Berger and Frey 2016). The academic and policy literature is replete with alternative definitions and measurements. Some studies focus on technical capabilities (BGT 2019), while others present overarching frameworks of underlying competences and behaviours (van Laar et al 2017, WEF 2020). These categorisations are designed to have general application across the economy but are remote from what is happening at the workplace. Unsurprisingly, there have been calls for greater contextualisation (Orlik 2018), and a closer examination of digital skills requirements in specific sectors and occupations (Brown et al 2018, Keep 2021). As Kispeter (2018:58) notes, 'the most important gap concerns information about digital skills from workplaces and from the perspective of workers', especially the lower skilled.

In this article, it is argued that a situated analysis is required which conceptualises digital skills in relation to wider skills and knowledge that are used in a job, and considers how these are shaped by the workplace, sector and national context. Crucially, this approach sees digital skill requirements as not simply flowing from technology but related to the specific work process and how jobs are designed. When digital technologies are introduced, the way that tasks and skills are reconfigured, and the opportunities and supports available for workers to learn digital skills, are subject to the influence of workplace actors. The influence of local managers, workers and their representatives cannot, however, be considered in isolation from national and sectoral institutions and actor power relations (Lloyd and Payne 2016, Gallie 2017, Dølvik and Steen 2018). Country comparisons are, therefore, essential to uncovering factors that may contribute to digital skill requirements in specific sectors and occupations (Krzywdzinski 2017, Lloyd and Payne 2019).

This article focuses on the experience of operatives in food and drink processing, and logistic porters and service workers in public hospitals, in Norway and the UK. These are two countries with starkly contrasting labour market and social institutions, and differ in the spread of digital skills across the general population. Such a comparison provides an opportunity to explore differences in the nature and complexity of digital skill requirements and the challenges presented for workers in lower-skilled jobs. Drawing on qualitative case studies, the article uses interviews with managers, unions and workers to address two central research questions. First, how demanding are digital skill requirements in these jobs and, second, how difficult are they to acquire? Overarching both questions is whether there are country differences.

The article makes three key contributions. First, it contributes to a more grounded understanding of the challenges confronting lower-skilled workers, and asks whether terms like a 'digital skills crisis' may risk exaggerating the complexity of some of these new skill demands. Second, it advances conceptualisations of digital skills by analysing them in relation to other skills and knowledge used within a job. Third, it considers the potential shaping effects of national institutions and workplace actors on digital skills.

The article begins with a critical discussion of the literature on digital skills and outlines the analytical approach of the study. The following section provides an overview of key institutional features of Norway and the UK, along with the technologies and sectors to be explored. The research methods are then outlined. Next, the findings section evidences the digital skills in use and how workers learn these skills. The last section, discusses the significance of the findings, including country similarities and differences. The conclusion addresses research and policy implications and highlights areas for further research.

Digital technologies, work and skills

Much of the literature surrounding digitalisation reflects the perspective that digital skills are increasingly important in the workplace, and that many low-skilled workers risk falling behind (Berger and Frey 2016, OECD 2019a). Accurate definition and measurement of digital skills is, therefore, seen as vital to assessing the scale of the challenge and for effective policy responses. Two broad approaches can be discerned. One focuses on digital skills as the ability to use a hierarchy of technologies or ‘tools’; the other seeks to measure digital skills within a framework of wider competences and behaviours.

The technical approach focuses on the use of specific digital tools, and categorises skill requirements from basic to advanced levels. Although this promises ease of measurement, there is little agreement where ‘basic’ starts and ends. BGT (2019:67), for example, identify ‘baseline’ skills linked to ‘productivity software’, such as Microsoft office, which ‘will get you a job’ (see also OECD 2004, Kispeter 2018). By contrast, Cedefop (2015) defines ‘basic’ skills as sending emails and browsing the internet, with word processing defined as a ‘moderate’ skill. The bluntness of the measures makes it difficult to capture the diverse uses of an application that may require different skill levels. One worker, for example, could use a spreadsheet just to read data, while another undertakes calculations and integrates multiple data sources.

The second broad approach to digital skills seeks to capture underlying competences and behaviours in the form of ‘comprehensive frameworks’ which can be applied across the economy (Kispeter 2018:56). These often overlap with discourses around employability skills, such as communication and problem solving (WEF 2020). One example is van Laar et al’s (2017) attempt to integrate digital skills with ‘21st century skills’. They identify seven core dimensions (technical, information management, communication, collaboration, creativity, critical thinking and problem solving), along with five contextual domains. Such frameworks tend to be ‘extremely vaguely specified’ (Keep 2021:15), typically involving broad-box categories which could include skills from very basic to highly complex. Invariably, these frameworks encounter problems of complexity and generalisability that make them difficult to apply to specific jobs and workplaces. Digital problem solving, for instance, could mean something quite different depending on whether you are a supermarket customer service assistant or a digital analyst in a software company.

A central weakness of this focus on abstract measurement and categorisation is that questions of skill complexity in use at the workplace are simply not addressed. In response, Orlik (2018), stresses the importance of context and providing an analysis of the particular skills needed by an occupational group, in a specific place and time period. While calls for greater contextualisation are welcome, it is also important to examine how digital skills relate to other skills used within a job (Bretschneider 2019, Conein and Schad-Dankwart 2019). Pfeiffer (2016), for example, argues that workers on automated assembly lines not only require digital skills to interface with technology but also use their tacit, experiential knowledge to smooth machine-created malfunctions. Seeing digital skills in the context of the work process and links to wider knowledge may also have implications for how these skills are used and learnt.

A further analytical step is required which sees digital skills as *not* simply flowing from technology. This allows the possibility of certain 'immanence' effects inscribed into a particular technology (Edwards and Ramirez 2017). A new robot, for example, contains a built-in procedure or menu which can be more or less complex to use, reflecting what Thompson and Laaser (2020) refer to as 'first-order choices' around technology design that occur prior to adoption in the workplace. However, decisions remain about which technology to purchase, whether a robot is integrated with other digital systems, are all its capabilities used, and how tasks and skills are reconfigured and distributed across different groups of workers. These 'second order choices' allow considerable indeterminacy (Thompson and Laaser (2022). The approach used in this article emphasises that 'choices' around technology, the organisation of work, the autonomy afforded to workers and the scope to develop and utilise skills are shaped, in part, by management decisions and any influence workers and their representatives can exert. These actors operate within national polities, institutional structures and power relations that have influence at multiple levels (Lloyd and Payne 2016, Gallie 2017, Krzywdzinski 2017).

The vocational education and training (VET) system is a part of these broader structures that may support or hinder organisations and workers to reskill for new tasks or jobs (Dellot and Wallace-Stephens 2017). Given national differences in lifelong learning opportunities, we might expect variation in workers' experiences of acquiring digital skills. Evidence suggests that where adult participation in learning is greater, there are higher ICT literacy skills among the general population (Martin 2017). Much of the policy literature focuses on formal training *outside* of the workplace for workers displaced by new technology, yet the few studies in this area indicate that informal learning and 'learning by doing' at work are essential (Pfeiffer 2016, Colla et al 2021, Warnhoff and de Paiva Larerio (2019).

Workers' age may also be a factor in how new digital skill requirements are experienced (Martin 2018). The OECD (2019b:39) notes that in 'all countries a significant age gap exists… younger generations… are increasingly fluent in the use of digital technologies, older people are often left behind.' However, Achtenhagen and Achtenhagen's (2019) research from German food processing plants presents a complex picture. Young apprentices often had 'difficulty transferring digital media competences which they have acquired in their spare time to work-related tasks' (2019:229). This finding suggests that learning digital skills *outside of work* is not the same as applying them *in work*, and reiterates the centrality of the work context.

Putting digital skills in context

Analysing digital skills in context requires grounded research at the workplace, within specific sectors and countries. This section outlines the main labour market institutions in Norway and the UK, relative measures of digital skill competence, and the technologies in food and drink processing and hospitals that are the focus of this study.

Norway is a 'Scandinavian welfare state' with powerful trade unions, multi-level collective bargaining, relatively generous welfare provision, and an enduring tripartite system involving cooperation between the state and peak-level employer and union associations (Løken et al 2013). Union density is 50% and collective bargaining coverage 69%, but is near universal in the public sector (Nergaard 2020). National collective agreements and the Work Environment Act provide rights for union and worker involvement in changes affecting work practices, including the introduction of technology. In core manufacturing, there is a long tradition of union involvement in technological rationalisation in support of productivity-driven competitiveness in a high-wage economy (Alsos and Trygstad 2018).

The influence of unions within public policy and at the workplace has, arguably, helped place Norway in the front rank of European nations for the proportion of jobs combining high autonomy and learning intensity, and for a relatively low incidence of 'Taylorist' and 'simple' jobs (Lorenz 2015, Gallie 2017). The education and training system can be seen as playing a supportive role (Lloyd and Payne 2016). A well-regarded VET system, rooted in social partnership, is built around the main '2+2' apprenticeship, involving two years of upper-secondary education, followed by two years of work-based training, leading to formal craft certification as a 'skilled worker' (Lund and Karlsen, 2020). Around a third of certificates are awarded to workers with at least five years' experience who have a legal right to take an equivalent test to apprentices, using the 'practice-based' route. In conjunction with the validation of prior learning, these workers often undertake short periods of study at adult vocational colleges. Research suggests colleges are adapting well to manufacturers' new skills demands resulting from digitalisation (Lund and Karlsen 2020).

The UK is typically characterised as a more liberalised economy, with weakened unions, limited employer coordination, a lightly-regulated labour market, and low unemployment benefits (Lloyd and Payne 2016). Less than one in four workers are unionised, with collective bargaining coverage at 39%, although rates are significantly higher in the public sector (DBEIS 2021). Relatively low labour costs, limited collective bargaining, and weak employment protection are held to contribute to low levels of capital investment and productivity (Lewis and Bell 2019). Workers and their representatives have no rights to be consulted over changes to working practices or technology unless redundancies are involved. Evidence indicates that the extent of consultation in practice is limited (van Wanrooy et al 2013:20-1). The relatively weak influence of unions on job design, in the workplace and at the level of public policy, may partly explain why the UK has significantly fewer 'discretionary-learning' jobs than Norway (Lorenz 2015).

Notwithstanding differences across the devolved nations in the UK, the VET system has relatively weak 'social partner' involvement. The bulk of initial VET is provided by further education colleges, alongside a small, 'all-age' apprenticeship system and in-work competency-based qualifications, both of highly variable quality (Wolf 2011). Employer engagement with the formal skills system, alongside their own training record, is an on-going problem (Keep 2020), with evidence of a long-term decline in employer-provided training (Green et al 2016).

In both the UK and Norway, the use of digital technologies by the general population is amongst the highest in Europe (EC 2021b: 20, 29). Possession of 'basic digital skills' is somewhat greater in Norway, but surveys[1] suggest both countries have a significant age gap. It is estimated 96% of those aged 16-24 in Norway, and 92% in the UK, have at least basic digital skills[2], which for 55-64-year-olds reduces to 75% and 60% respectively. The differences between the two countries are most apparent when introducing education level. Only 13% of those aged 25-64 with a 'low formal education' in the UK possess at least basic digital skills, compared to 64% in Norway.

[1] Eurostat ISOC_SK_DSKL_I 2019
[2] For definition of basic skills see: https://ec.europa.eu/eurostat/cache/metadata/en/tepsr_sp410_esmsip2.htm#compar_geo1614262630695

The contrasts between the two countries might lead us to expect differences in the job tasks allocated to those in lower-skilled jobs, including those associated with digital technologies. Norwegian unions generally have more influence over the implementation and use of technology, and this may lead to a greater tendency for workers in lower-skilled jobs to be reskilled to undertake more complex digital tasks than in the UK. Both countries have a significant age gap in digital proficiency, and we would therefore expect older workers to experience more challenges, especially when combined with low formal education.

This article focuses on two types of robots that perform 'physical tasks' (Fernández-Macías et al (2021:77), along with associated digitalised logistics and production management systems. In food and drink processing, the main technologies impacting on those in lower skilled jobs are industrial robots, defined as digitally-controlled machines, used for physical manipulation with at least three axes of operation, and pre-programmed functions (Fernández-Macías et al 2021). Research on their impact on operatives is rare and does not focus on digital skills (Achtenhagen and Achtenhagen 2019, Lloyd and Payne 2021a). Studies in other areas of manufacturing indicate considerable variation in digital skill requirements, from simply 'pressing buttons' (Moniz and Krings 2016) and completing forms on an ipad to use of applications, basic programming and more 'cognitive' demands (Rolandsson et al 2019:21, Warnhoff and de Paiva Lareiro's 2019).

Automated-guided vehicles (AGVs) are programmable transport robots that are used in some hospitals to assist with logistics (Pedan et al 2017, Benzidia et al 2019, Lloyd and Payne 2021b). Originally developed for manufacturing environments, AGVs use navigation technologies, such as lasers, magnets and sensors, to move carts or wagons around designated areas within the hospitals. Most of the manual tasks of moving medical supplies, waste, food and linen, previously undertaken by logistic porters, can be replaced. Benzidia et al's research (2019) is a rare study of hospital AGV systems that makes some reference to skill requirements.

They see potential for ‘professonalising’ logistics personnel as workers require ‘information technology and information systems knowledge’ (2019:289, 287). However, little detail is provided on the type and depth of such skills and knowledge.

There are few studies that attempt to uncover specific changes to digital skills in the context of wider skills required within a job and which examine potential differences related to the institutional context. The next section outlines the research methods used to address the two main questions: how demanding are the digital skill requirements in these jobs and how are they learnt.

Research method

The research used a comparative multi-case study method involving semi-structured interviews to probe workplace actors’ views of digital skills. Ten workplace case studies in Norway and the UK were undertaken in 2018 and 2019, five in food and drink processing plants and five in hospitals (Table 1). Relevant sites with robotic technologies were identified from industry press and discussions with national employer and union organisations. Access was negotiated through direct email inquiries to organisations or via existing contacts in national unions.

In the hospital sector, all the sites were large, general hospitals (over 5000 employees) that were using AGV systems. The two UK cases were located in Scotland. As with the Norwegian hospitals, they had high levels of union membership, reflecting the hospital sector in general, and there was a ‘social partnership’ approach to employment relations (Bacon and Samuel 2017). The food and drink cases were more diverse, comprising three drinks processors, and two manufacturers of ambient foods, with different technologies and levels of automation. The Norwegian plants were strongly unionised, whereas those in the UK were non-union establishments. Collective bargaining coverage in the sector is around 56 percent in Norway (Nergaard 2020), compared with under 30 percent in the UK (Wilson 2013). While some caution is, therefore, required in making direct comparisons, these workplaces are more typical of their respective country sector than they are exceptional.

Table 1: Cases and interviews

Cases	Subsector	Interviews			
		Managers/ supervisors	Engineers, technicians & trainers	Workers	Union reps
N-Drinks1	Drinks	1		2	4
N-Drinks2	Drinks	4	1	2	3
N-Food	Confectionary	2	1	3	1
UK-Food	Sandwiches	3	1	2	
UK-Drinks	Drinks	2	2	1	
N-Hosp1	Hospital	5	2	2	4
N-Hosp2	Hospital	3	1	4	1
N-Hosp3	Hospital	1	1	2	1
UK-Hosp1	Hospital	3		2	2
UK-Hosp2	Hospital	2		1	2

The research draws on interviews with managers, trainers, engineers, workers operating digital technology, and union representatives. Probing skill complexity through the subjective perceptions of interviewees can be problematic. Asking a manager about the skills of an operative assumes they understand what is involved, while job holders may underrate practiced skills or 'tacit' knowledge that can be hard to tell (Kusterer 1978). Nevertheless, interviews remain a useful method for examining job skills, and the triangulation of data from different perspectives can aid validation (Flick 2004). In total, 74 semi-structured interviews were conducted (Table 1). Those with managers, trainers, engineers and technicians lasted 60 to 90 minutes, and focused on the use of technology, digital and wider skill needs and acquisition. Workers and their representatives were asked about their views on technology, the skills required in their jobs, training received, how they learnt the skills, and the challenges faced, with interviews ranging from 30 to 60 minutes. A guided tour of each workplace was undertaken where the authors observed the robots, talked with guides and workers, and took field notes.

All interviews, except one, were audio-recorded and transcribed verbatim. These were analysed thematically using a coding schema derived from the research questions and literature. A small sample of interviews were initially coded, with some additional codes added following discussions between the authors using an inductive and iterative approach to ensure key data were not missed (Rivas 2012). All interviews were read to ensure deep immersion in the data and were revisited where questions arose around interpretation and subtle differences between cases. Where issues required further clarification, these were followed up through email with key contacts, and interviews cross-checked with field notes to strengthen validity.

The workplace context

The research focuses on changes to lower-skilled manual jobs that typically do not require entry qualifications and where initial training mainly takes place on-the-job. In the food and drink sector, the research included process operatives which are a heterogeneous group both within and across workplaces. In hospitals, the workplaces were quite similar, but the range of jobs was broader, including logistic porters, service workers and operatives who worked with AGVs.

In food and drink processing, the extent and type of robotics used varied considerably. A key country distinction is the higher levels of automation in the three Norwegian plants, with robotics first installed in the 1980s and 1990s. In the two UK workplaces, robots had only been introduced within the last five years. Wages in the Norwegian plants were typically around double those in the UK, reflecting the strength of unions in Norway, and were seen by management and unions as a key driver of automation. Robots were used primarily for feeding machines, packaging and palletising, and had replaced many physical manual tasks. At N-

Food, other types of robots were also used in the making of products, such as pick-and-place and mould-laying. UK-Food was distinctive with very low levels of automation. Robots were limited to a small packing area, and most workers were only undertaking repetitive manual tasks.

Across the cases, operatives had different roles and responsibilities. These ranged from dealing with a single robot to running several different types of robots or overseeing one or several robotic lines. Interviews in Norwegian plants revealed considerable union involvement in the introduction of technologies. Union representatives emphasised their role in pushing management to retrain existing operatives to use digital technologies. More generally, the interviews indicated that Norwegian operatives had more responsibility, broader job roles and greater autonomy compared with the UK. While in the UK there was a first-line supervisory role, Norwegian operatives typically worked without direct supervision, reporting to departmental managers. With the exception of UK-Food, it was estimated to take between six months and two years for a new operative to become fully competent. At UK-Food training took place over a few days. In Norway, external recruitment to these roles was shifting primarily towards apprenticeships, and in UK-Drinks towards a mix of experience and apprenticeships.

In the hospital workplaces, AGVs were introduced between 2006 and 2015 when the hospitals were built, and formed part of a digitalised logistics system. Logistics personnel who worked with AGVs undertook a range of jobs, with some country differences. In Norway, a new role of 'AGV operative' had been introduced with responsibility for directing and monitoring operations on a computer, and identifying and solving problems. In the UK, these tasks were mainly the preserve of supervisors or managers, with some logistic porters trained to check the computer monitors and to resolve minor problems. AGV systems encounter regular issues throughout the day, such as a robot automatically stopping when an item is in its path, full loading bays leading to blocked queues, or a dirty sensor interfering with navigation. Workers may have to 'reboot' the AGV for it to restart or clean the sensor, with more complex programming or mechanical problems referred to technicians or engineers.

Other logistics porters and service workers primarily interact with the AGV through manually loading and unloading materials into and out of the carts or wagons that are transported by the AGVs, and scanning information into the system to direct AGVs to the drop-off and collection points. Some of these service workers in Norway are responsible for checking ward stock levels and ordering replacement supplies using digital tools linked into the logistic systems. None of these jobs in either country require any qualifications, and initial training takes a couple of weeks, primarily by shadowing experienced workers, alongside basic induction and statutory training. The next two sections address, first, the digital skill requirements of these jobs, together with some specific examples of links to wider skills and knowledge and, second, how workers learnt these digital skills.

Digital skills and links to wider skills and knowledge

Figure 1 is a pictorial representation of the most complex digital skills undertaken in the different jobs across the cases. Those not using any digital technologies are excluded. In food and drink plants, where digital skills use among process operatives in each workplace varied, they are shown as stretching across two or more skill categories. For example, at N-Drinks2, operatives on the automated picking system had the most complex digital skill demands of all the cases, while those on some of the production lines only used menu systems. In comparing across the cases, the simplest skills involved 'scan and receive' via a digital device, such as a smartphone or tablet, whereas the most complex required workers to use multiple control systems, manipulate, adjust and monitor data. Under most digital skills frameworks (Kispeter

2018, BGT 2019 EC 2021b), these requirements can be captured within entry-level or basic skills, and do not reach into higher levels, such as programming, design or maintenance.

[**Figure 1: Digital skill requirements in case study jobs]**

Hospital logistic porters and service workers are the most limited in their use of digital technologies, only scanning and receiving notifications using a digital device. At N-Hosp2, porters used hand-scanners in what was described as simply 'you scan it and tell it [the AGV] where you want it to go' (AGV team leader). Similarly, a manager (S-Hosp1) remarked: 'they just press a button, that's an automatic return for an AGV, so that's it.' For service workers in Norway, responsible for replenishing and ordering supplies on the wards, digital skills were also very basic, involving the use of a hand-held scanner to scan a barcode on a storage tray when an item was running low.

For the position of AGV porter in the UK, tasks were expanded to include acting as a first-line responder when problems occurred. Workers interpreted data images on the computer screen, used a basic menu system, and were responsible for 'rebooting' the robots if they became 'stuck' by following a few simple menu prompts. These tasks were considered to involve very limited digital skills. In the case of rebooting the AGV, a line manager at S-Hosp2 explained:

> Just follow a set of steps… your screen will come up [on the AGV] and you'll see the black triangles… if it's red or pink… drive on ahead… update the zoom update, continue, and it will follow the orders through.

In the Norwegian hospitals, the new job of 'AGV operative' covered more complex tasks normally undertaken by supervisors or line managers in the UK. These included basic use of applications and adjusting the system. Since operatives had overall responsibility for the monitoring process, they also required a broader awareness of the logistics' operation as a whole. An AGV operative at N-Hosp2 explained that the job needed 'someone that can understand the system... read the screen and have an easy understanding for the data system… there's a logic that's very important to learn'. A manager commented how these workers had to learn 'new software and that's always a difficult part for anybody' (AGV manager, N-Hosp3).

Digital skill requirements in the food and drink plants were far more variable in levels of complexity. At UK-Food, digital skills were the most limited. A small group of workers were trained as robot operatives, responsible for overseeing one caged packing robot each, hand-feeding empty boxes, removing full boxes, and hand-wrapping pallets. The digital part of the job involved following simple menu prompts to set-up, start and stop the line. The line manager explained: 'they don't have technical adjustments to make… it tells them on the screen, wind this handle until that number says this.' As one robot operative confirmed, 'it's touchscreen… it's straightforward.'

At UK-Drinks, while the use of robotics was greater, and operatives' jobs more complex, digital skills requirements remained limited. A trainer again referred to a menu with basic prompts: 'you've got a screen comes up in front of you. 'Is that right?' 'Yes/no.' 'Is it wrong?', and basically answering a series of questions as you go through. It's nothing.' A supervisor felt 'you just need patience, just watch people, ask. It's not rocket science.' Other digital skills included using keyboards to input and read data from the quality assurance system. At the Norwegian plants, there were some similarities. An operative at N-Food spoke of the technology being 'more difficult' and having 'to learn to use the programme', although much of this was touch screen, for example adjusting temperatures.

The most complex digital skill demands were found on the automated picking systems at N-Drinks2, where 80 percent of the operatives' time was spent on the computer. As a logistics manager noted: 'you have to monitor the system, you have to check up everything, how it's going and [if] the flow is ok, if somewhere it's stopping so then you have to find out where it is and why it's stopped.' These workers were required to solve problems using the computer technology, often involving communication with other departments, in a job that had become less manual. An operative referred to 'more complicated menu systems' involving various warehouse management packages that linked into other departments' supplies and orders from customers.

How do digital skills relate to wider skills and knowledge within the job? Reference was made to training times and job complexity in the previous section. Here, some examples are used to illustrate these broader linkages. In food processing, it can be argued that the application of digital skills becomes more complex when the production process relies heavily on workers' experiential knowledge of products or processes. At N-Food, many operatives had worked in the factory for at least 10 years, undertaking a wide range of tasks from cooking, tasting, running the robotic and automated lines, and manual repetitive operations. Experiential knowledge, including sensory awareness, was particularly important for some workers as ingredients and cooking processes vary, even with changes in the weather. At N-Food, workers were required to touch, smell and taste the confectionary products and to adjust the digital programmes to take account of environmental conditions. An operative described the links between product knowledge and digital skills: 'we check the taste and the look… then we adjust the machine'. Such knowledge was said to be 'not easy to pick up' (technical manager), and 'really difficult to train' (maintenance worker). Similarly, at N-Drinks1, an operative described how the yeast varied with conditions and had to be looked after 'like a baby'. This inability to standardise the production process meant that although digital skills could be relatively basic, they can only be effectively deployed by drawing on a broader experiential knowledge which rendered their *application* more complex.

In hospitals, the broader skills and knowledge required were more limited. The AGV operatives in Norway who ran the system were using digital skills at least as complex as those at N-Food and N-Drinks-1, yet it took only two to four weeks to learn the job. Some interviewees suggested that a broader knowledge of logistics was required in terms of flows of materials, potential obstacles and timings of deliveries. A manager at N-Hosp3 considered that learning to operate AGVs was ‘easy’ but to ‘understand the concept has been a bit harder.’ However, there is no evidence that this required formal training courses. For logistics and service porters across the UK and Norway, the digital skills for scanning are straightforward but it takes new workers a few weeks to become familiar with the hospital layout, department names and routines. Given such varied patterns in the relationship between digital skill levels and the broader skills and knowledge required in the job, how are digital skills acquired?

Learning digital skills

Workers learnt specific digital skills predominantly through on-the-job training and learning-by-doing. None of the existing workers were required to take external courses or qualifications on digital skills, which suggests the formal VET system was of limited relevance to these elements of their jobs. In food and drink processing, when a new robot is installed, the supplier company is typically on site for one or two days to provide training for workers *in situ*. When a new robotic *system* is introduced, such as the robotic picking system or AGVs in hospitals, more extensive training is provided as the installation process can be complex, sometimes taking several months.

Once the technology is in place, new workers learn with the help of an internal trainer, line manager or co-worker. It is quite difficult to separate the time taken to learn the digital elements from the rest of the job. In UK-Drinks, new line operatives took three to six months to train, while it was claimed that the digital skills could be picked up almost straight away.

> I’ve had a new trainee this morning who I was doing a test with, and I was getting him to enter the figures in as I was doing the test with him, so, you know, a matter of minutes. (trainer)

For the more complex roles in N-Drinks2, the time taken to retrain an existing manual packer to become an operative on the robotic picking system was at least three months. As a supply chain manager explained:

> 'everything is more or less on computers because then you can see how this is the whole flow in one set-up and so they follow this. So they need to be quite skilled in the computer.'

When the system had been introduced, the union was instrumental in ensuring that the more complex new tasks of overseeing the lines were designated as an operative role rather than that of a technician-level worker. That some workers struggled to learn the new role underlines the relative complexity of skill requirements of these particular jobs at N-Drinks2:

> we kind of agree on some people that we think are not skilled enough but they [the unions] say you need to take them. …some people fly and some people take three months, six months, nine months and they just don't make it, they can't learn it, it's too difficult (HR manager).

In the hospitals, AGV operatives in Norway and AGV porters in the UK took between two to four weeks to learn the job, which included using software packages and hand-held digital devices comprising menu-driven applications. Some problems with the systems occur intermittently and, therefore, knowledge is acquired over a longer period through 'trying and doing'. For logistic porters and service workers using hand-held scanning devices, their initial training across the two countries was around two weeks, and the digital element of the job was only a small part of the learning requirements.

Although the digital skills in these jobs may be defined as 'basic', workers experience them differently. The most common response from interviewees was that younger workers found the digital demands more straightforward, in that they already possessed the foundations through using computers, tablets and smart phones in their everyday lives. For some older workers, particularly those who had been doing the same job for decades, these demands could be quite challenging.

> we've got some people that have been here for 25, 30 years, you don't necessarily keep up with the times… if you've been hand-packing on a line for 10 years…then you bring robots in… sometimes it's a bit harder. (team leader, UK-Drinks)

> I need someone that can understand the system... read the screen and have an easy understanding for the data system… There are some people that have never touched a PC; you cannot ask this person [to do the job]. (AGV operative/lead, N-Hosp2)

The picture, however, is not a simple one. In the food and drinks processing plants, older experienced workers were often seen to have advantages over their younger counterparts due to their experiential knowledge of processes and products gained over many years.

> There's a lot of knowledge in older workers… Takes years to get real people to that stage, experience… a computer can't fix everything. (shop steward, N-Drinks1)

> If you have responsibility for four or five machines… what is in the bottle, if caps are closed properly, if the label is glued enough, if the label is there. It's a lot of things. It needs a lot of time to learn, and you need a lot of patience. (supervisor, UK-Drinks)

At N-Food, experienced operatives with a 'feeling for the product' could acquire the digital skills to work a robotic line within a week, whereas new recruits required two years to be fully trained for the job. As one manager noted:

> new people are coming in… they're pushing on a screen, reading user manuals… it's not hard for them at all, but they lack this feeling…of how the product should be, the texture for example.

Overall, there appeared to be little difference across countries in the concerns raised about workers' ability to learn to use digital technologies, although more issues were raised where skill demands were higher. Working with robots did not require any formalised qualification, nor did it necessarily lead to *qualified* work in any of the workplaces. In UK-Drinks, around 50 existing workers were studying for level 3 national vocational qualifications with a local training provider. These qualifications were not considered necessary for the job and the production manager admitted they were providing these opportunities because of government-funding. They were open to workers whether or not they used robotic technology, and completion did not lead to higher pay. In both sectors in Norway, workers with sufficient experience were able to access local college training and gain craft qualifications to become a 'skilled worker' through the 'practice-based' route. Such status affords additional pay supplements of around 10 percent as part of collective bargaining agreements; however, it was not considered a primary way to learn digital skills.

Discussion

The study indicates that there are variations in the types and complexity of the digital skills in use across sectors and workplaces. Many jobs were limited to using digital scanners or simple menu systems, while at the higher end workers were dealing with multiple applications and different data sources. Some country differences could be observed. The most complex digital skills in food and drinks processing were found in Norway at N-Drinks2 and, in hospitals, among Norwegian AGV operatives. In the case of N-Drinks2, where the digital technologies were more advanced than in the other plants, operatives were upskilled to undertake the more complex tasks. Unions had been key to ensuring operatives took on this work rather than it being designated as part of a technician's job. For AGV operatives in Norwegian hospitals, the technology was similar to that used in the UK, but they were undertaking digital tasks reserved for line managers or supervisors in the UK. Although these examples are consistent with expectations of higher digital skill use in Norway, this was not the case for many other jobs where demands were quite similar.

Explaining these country similarities and differences is not straightforward. There are different technologies in use in the food and drink processing plants and these can be seen to have certain 'immanence' effects on the digital skills required to use them. Decisions over whether and what types of robotic technology to introduce, and how tasks are then reorganised, are important factors in shaping the digital skills used by operatives. These may be influenced by institutional structures and power relations, including the role of trade unions and the VET system. In the Norwegian plants, unions were actively involved in the introduction of new technology through representation on plant-level boards and/or on project groups. Union representatives saw new technology as essential for delivering high-wage, productivity-driven competitiveness, and sought to reduce routine, physically demanding work. In the two non-union UK plants, there were no formal mechanisms for influence over technology decisions, job design or skills training (Lloyd and Payne 2021a). While it is difficult to be precise about how unions impact on digital skill requirements, they clearly played a role in the distribution of digital skills among different groups of workers and in relation to broader aspects of job design.

In hospitals, the AGV systems were very similar across countries and although there was little variation in the digital skill requirements, there were differences in how jobs were reconfigured. As with N-Food2, existing logistic porters in Norway were upskilled to oversee the system, whereas first-line managers undertook this role in the UK. Unions were involved in the introduction of AGVs in both countries, although not in the decision to use them. Their role was mainly consultative and focused on fair treatment, health and safety, and redeployment. The data does not suggest these differences in the division of digital tasks and responsibilities reflect greater union workplace influence in Norway; nevertheless, they are consistent with Norwegian workplaces tending to devolve more responsibilities to workers (Gallie 2017).

Workers across the Norwegian case studies in the two sectors tended to work without direct supervision, had more autonomy in the job, and had opportunities to gain 'skilled worker' certification that provides additional pay. 'Skilled' status reflects Norwegian unions' historical role in shaping the VET system and their success at achieving qualifications-based pay through collective bargaining. However, there is little evidence that the VET system itself is the key factor accounting for country differences in job design in either sector. A more convincing explanation is higher labour costs and the strength of unions at the workplace and in national policy making. Together, these factors help to shape less hierarchical management cultures and shared expectations that workers can, and should, be trusted to work without close supervision (Dølvik and Steen 2018).

Notwithstanding some differences in digital skill requirements across the cases, for many of the jobs, in both countries, these remained quite basic. They could, for example, be compared to everyday simple use of a mobile phone, such as scanning a code, or to a menu system that is encountered when buying a train ticket at a self-service machine. For most workers, therefore, the fundamentals of these digital skills are learnt in everyday life. Yet, some individuals still struggle with learning to use the technology, even if the numbers appear relatively small. While caution is needed to avoid generational stereotypes, some older workers were said to experience more challenges than younger colleagues (see also Martin 2017), having less exposure to digital devices outside of work.

If we look at wider skills and knowledge, the findings reveal that it is these elements which were often more demanding than the digital skills aspects of the job. These broader skills were more apparent in some of the food and drinks processing plants, where many operatives were expected to run one or more production lines and fix minor machine malfunctions (Pfeiffer 2016). In some cases, workers drew on their experience to make fine adjustments to the process because of the non-standard nature of the ingredients, and without this 'feeling' for the product could not operationalise their digital skills. These other tasks explain why at N-Food, for example, an experienced operative can pick up the digital skills required to work with a new robot within a week, while a 'tech-savvy' new recruit can take two years to learn the job.

The interviews suggest that younger workers may help older workers with new digital skills requirements. Similarly, older workers retain advantages in experience which can only be learnt over time, and can help new recruits learn the job. Again, the picture is not a simple one. The balance between these different skills varies, with some of the jobs in food processing requiring lengthy periods to acquire the knowledge of products and processes. In other cases, digital skills took the same time to learn as other aspects of the job. In the case of an AGV operative in hospitals in Norway, the digital skills were similar in requirements to some of the food processing plants. However, the time taken to learn the broader skills could be just a couple of weeks.

It is important, therefore, not to overstate the skills and knowledge required in some of these jobs. Findings from the hospital cases question Benzidia et al's (2019) claim that AGV systems require logistics knowledge at a level that might lead to the 'professionalising' of logistics staff. For some food and drink process operatives (e.g. UK-Food), their jobs were very routine and, while they were required to spot and report machine errors, were far removed from the more complex demands reported in Pfeiffer's (2016) study of assembly work.

Conclusion

There are major policy concerns surrounding the digital skills challenge or 'crisis', particularly for lower-skilled workers (HSTC 2016, OECD 2019a). This article has argued that digital skills need to be studied in the workplace, and analysed in relation to wider skills and knowledge used in the job, located within the national institutional, and sectoral context. This approach informed a comparative study of the digital skills required of operatives in food and drink processing, and logistics porters and service workers in hospitals, in the UK and Norway. It sought to uncover how demanding are the digital skill requirements in these jobs, how workers learn these skills, and whether there are country differences?

In both countries and sectors, digital skills required in these jobs would, in most formal classifications, be categorised as 'basic' (Kispeter 2018, BGT 2019, EC 2021b). However, there are substantive differences between using a digital scanner and working with multiple applications and data sources, which suggests that existing measures of digital skills are too blunt to be able to identify skill needs or capabilities. For most workers, digital skills learnt in everyday life are then applied to new situations in work, primarily through short work-based training and/or learning-by-doing. Even the more complex digital skills identified in some of the cases do not require workers to have formal qualifications or more than very short periods of off-the-job training.

Notwithstanding surveys reporting wider digital competency divides in the UK, related to age and education, compared with Norway (OECD 2019b), there was little evidence that UK workers in this study encountered more problems learning basic-level digital skills. Although it is important to consider age when it comes to acquiring even basic digital skills, the relationship with broader job demands should not be overlooked. Younger workers may have advantages in learning digital skills at work, at least in a narrow sense. Experienced workers have valuable in-work knowledge, particularly in jobs where experiential knowledge of process and product is key, which renders the application of digital skills *in situ* more complex (Pfeiffer 2016).

In both sectors, the study found that Norwegian lower-level workers tend to work with less supervision and have more autonomy than their counterparts in the UK. These differences in job design appeared to have an impact in increasing digital skill demands in some jobs, with operatives upskilled to take on more complex activities that were normally the preserve of technicians or line managers in the UK. These findings are consistent with previous studies that highlight the distinctiveness of Scandinavian countries in patterns of work organisation, and the central role played by labour market institutions and unions (Lorenz 2015, Gallie 2017, Lloyd and Payne 2016). Evidence of a direct union effect on digital skills use was found in one of the Norwegian food and drink cases, but the lack of data on past decision processes in other organisations does not allow broader conclusions to be drawn. That said, Norwegian workers have opportunities to gain skilled worker accreditation, linked to higher pay, reflecting unions' historic role in shaping such arrangements.

This study indicates that existing measurements and definitions of digital skills are of limited value in understanding actual requirements within specific sectors and occupations and the challenges presented for workers. Using technical classifications (Kispeter 2018, BGT 2019) might provide some indication of people's exposure to digital technology but does little to identify whether and how their skills are, or could be, adapted to the workplace. Frameworks which aim to capture underlying competences and behaviours in '21st century' workplaces (van Laar et al 2017, WEF 2020) attempt to bring in other skills deemed important for employability and the exercising of digital competence – many of which have populated similar lists stretching back decades (Keep and Payne 2004). Whether these so-called 'generic', 'soft' skills and capacity for learning are critical for many lower-skilled, occupations today, however, remains questionable (Keep 2021). Such frameworks tell us little about what a competence, like 'digital problem solving', actually means in relation to specific occupations and jobs, and requires researchers to delve beneath generic categories and labels (Grugulis and Lloyd 2010).

The study makes an important contribution to the conceptualisation of digital skills. It moves beyond viewing digital skills in a narrow sense as something determined simply by technology, and underscores the value of analysing them in context and in relation to other skills, knowledge and experience. A 'whole job' perspective of this kind can go beyond abstract measurements and generalised frameworks, and help to inform grounded studies at the workplace that probe questions of complexity and learning demands. In addition, it draws attention to the critical role of workplace learning in understanding digital skills use and acquisition. A cross-national comparative lens also begins to open up complex questions around how jobs are redesigned when new technology is introduced.

In terms of public policy, the main conclusion is to caution against exaggeration of the *scale* of the digital skills problem, at least in terms of the demands made on workers in some low-skilled jobs. This is not to deny that there are some digital skills gaps in the workforce, nor does it detract from the need to tackle digital divides in wider society. It does, however, indicate that a more nuanced approach is required to digital skills provision; one that recognises that digitalisation may not lead to mass job losses (Acemoglu et al., 2020, Klenert et al., 2021). In addition, this study suggests that current processes of digitalisation may not involve radical transformations in requirements for digital skills, rather in many workplaces it may be more about small-scale reskilling and incremental change.

Inevitably, the study has certain limitations. A key issue for comparability is the absence of union establishments in the UK food and drink processing companies. It is also important to avoid generalising these findings to other lower-skilled jobs in the sectors studied, or indeed other sectors. Future research could extend the analysis to other lower-skilled work, including across unionised establishments, within and between countries. Research on how younger and older workers 'exchange' skills and experience at the workplace in a context of digitalisation may also generate valuable insights. It is hoped that other studies can shed further light on digital skills at the workplace, moving us beyond abstract and de-contextualised framings of the digital skills problem.

References

Acemoglu, D., LeLarge, C. and Restrepo, P. (2020) 'Competing with robots: firm-level evidence from France'. AEA Papers & Proceedings, 110,333-388.

Achtenhagen, C. and Achtenhagen, L. (2019) 'The impact of digital technologies on vocational education and training needs', *Education and Training*, 61(2):222-233

Alsos, K. and Trygstad, S. (2018) 'Workplace democracy: Representation and participation gaps in the Norwegian labour market model.' In: Engelstad, F., Holst, C. and Aakvaag, G. (eds) *Democratic State and Democratic Society: Institutional Change in the Nordic Model.* Warsaw: De Gruyter, 232-254.

Arntz, M., Gregory, T. and Zierahn, U., (2016) 'The risk of automation for jobs in OECD countries: A comparative analysis', *OECD Social, Employment, and Migration Working Papers*, 189, Paris: OECD.

Bacon, N. and Samuel, P. (2017) 'Social partnership and political devolution in the National Health Service: emergence, operation and outcomes,' *Work, Employment and Society*, 31(1):123-141.

Benzidia, S. Ageron, B., Bentahar, O. and Husson, J. (2019) 'Investigating automation and AGV in healthcare logistics: a case study based approach', *International Journal of Logistics Research and Applications*, 22(3):273-293.

Berger, T. and Frey, C. (2016) 'Structural transformation in the OECD: Digitisation, deindustrialisation and the future of work', *OECD Social, Employment and Migration Working Paper*, 193, Paris: OECD.

BGT (Burning Glass Technologies) (2019). *No Longer Optional: Employer Demand for Digital Skills*, BGT&DCMS, 03/2019.

Bretschneider, M. 2019 'What happens in the field is crucial!', BWP Special Edition VET 4.0 in Germany (Offprint), Bonn: Federal Institute for Vocational Education and Training.

Brown, P., Lloyd, C. and Souto-Otero, M. (2018) *The Prospects for Skills and Employment in an Age of Digital Disruption: A Cautionary Note*, SKOPE Research Paper No.127, University of Oxford, Centre on Skills, Knowledge and Organisational Performance.

Cedefop (2015) *Skills, Qualifications and Jobs in the EU: the Making of a Perfect Match? Evidence from Cedefop's European Skills and Jobs Survey.* Luxembourg: European Union.

Cedefop (2016), 'The great divide: digitalisation and digital skill gaps in the EU workforce', *#ESJsurvey Insights*, No.9, Thessaloniki: Cedefop.

Colla, V., Matino, R. et al (2021) 'Human-centered robotic development in the steel shop: improving health, safety and digital skills at the workplace', *Metals*, 11:647, https://doi.org/10.3390/met11040647

Conein, S. and Schad-Dankwart, I. (2019) 'Similar and yet different – digitalisation and its consequences for individual occupational profiles', BWP Special Edition – VET 4.0 in Germany, Bonn: Federal Institute for Vocational Education and Training.

Curtarelli, M., Gualtieri, V., Shater Jannati, M and Donlevy, V. (2017) *ICT for work: Digital Skills in the Workplace.* Luxembourg: European Union.

Czaja, I. and Urbaniec, M. (2019) 'Digital exclusion in the labour market in European countries: causes and consequences', *European Journal of Sustainable Development* 8(5):324-336.

Dellot, B. and Wallace-Stephens, F. (2017) *The Age of Automation: Artificial Intelligence, Robotics and the Future of Low-skilled Work.* London: RSA.

DBESI (2021) *Trade union statistics 2020,* Department of Business, Energy and Industrial Strategy.

DESI (2019) *Human Capital: Digital Inclusion and Skills*, Digital Economy and Society Index Report 2019 Human capital. https://ec.europa.eu/newsroom/dae/document.cfm?doc_id=59976, accessed 16/11/2021

Dølvik, J. and Steen, J (2018*) The Nordic Future of Work: Drivers, Institutions, and Politics,* Copenhagen: The Nordic Council of Ministers.

EC (European Commission) (2017) *ICT for Work: Digital skills in the Workplace 2017,* Luxembourg: European Union.

EC (2021a) 'Shaping Europe's digital future: Digital skills and jobs,' https://digital-strategy.ec.europa.eu/en/policies/digital-skills-and-jobs

EC (2021b) International Digital Economy and Society Index 2020 SMART 2019/0087 Final Report. Luxembourg: European Union.

Edwards, P. and Ramirez, P. (2016) 'When should workers embrace or resist new technology?' *New Technology, Work and Employment* 31(2):99-113.

Fernández-Macías, E., Klenert, D. & Antón, J.-I. (2021) 'Not so disruptive yet? Characteristics, distribution and determinants of robots in Europe'. *Structural Change and Economic Dynamics*, 58:76-89.

Flick, U. (2004). 'Triangulation in qualitative research'. *A Companion to Qualitative Research*, 3:178-183.

Frey, C. and Osborne, M. (2017) 'The future of employment: how susceptible are jobs to computerisation?' *Technological Forecasting and Social Change*, 114:54-280.

Gallie, D. (2017) 'The quality of work in a changing labour market', *Social Policy and Administration*, 51(2):226-243.

Green, F., Felstead, A., Gallie, D., Inanc, H. and Jewson, N. (2016) 'The declining volume of workers' training in Britain.' *British Journal of Industrial Relations* 54(2):422-448.

Grugulis, I. and Lloyd, C. (2010) 'Skill and the labour process: the conditions and consequences of change'. In: Thompson, P. and Smith, C. eds. *Working Life: Renewing Labour Process Analysis: Critical Perspectives on Work and Employment* Basingstoke: Palgrave Macmillan, pp. 91-112.

HCSTC (House of Commons Select Committee on Science and Technology) (2017) *Digital Skills Crisis: Second Report of Session 2016/17*, London: House of Commons.

Keep, E. (2020) 'Employers, the ghost at the feast'. *Journal of Education and Work*, 33(7-8):500-506.

Keep, E. (2021) 'Initial thoughts on policy issues for the future of work'. Digital Futures of Work Research Programme, Working Paper 3.

Keep, E. and Payne, J. (2004) ''I can't believe it's not skill': The changing meaning of skill in the UK context and some implications', In: G. Hayward and S. James (eds.) *Balancing the Skills Equation: Key Issues and Challenges for Policy and Practice*, Bristol: The Policy Press, pp 53-76.

Kispeter, E. (2018) 'What skills do adults need to succeed in the workplace now and in the next 10 years?' Digital Skills and Inclusion Research Working Group Evidence Brief, Coventry: Warwick University, Institute of Employment Research.

Klenert, D., Fernández-Macías, E. and Antón, J.-I. (early view) ‚Do robots really destroy jobs? Evidence from Europe', *Economic and Industrial Democracy*.

Krzywdzinski, M. (2017) 'Automation, skill requirements and labour use strategies: high-wage and low-wage approaches to high-tech manufacturing in the automotive industry', *New Technology, Work and Employment* 32(3):247-267.

Kusterer, K. (1978) *Know-How on the Job*. Greenport: Westview.

van Laar, E., Van Dijk, J., Van Deursen, A, and de Haan, J. (2017) 'The relationship between 21st-century skills and digital skills: A systemic literature review', *Computers in Human Behaviour*, 72:477-588.

Lewis, P. and Bell, K. (2019) 'Understanding the UK's productivity problems: New technological solutions or the case for the renewal of old institutions', *Employee Relations*, 41(2):296-312.

Lloyd, C. and Payne, J. (2016) *Skills in the Age of Over-qualification: Comparing Service Sector Jobs in Europe*, Oxford: OUP.

Lloyd, C. and Payne, J. (2019) 'Rethinking country effects: robotics, AI and work futures in Norway and the UK'. *New Technology, Work and Employment* 34:3: 208-225.

Lloyd, C. and Payne, J. (2021a) 'Food for thought: Robots, jobs and skills in food and drink processing in Norway and the UK'. *New Technology, Work and Employment* Early View.

Lloyd, C. and Payne, J. (2021b) 'Fewer jobs, better jobs? An international comparative study of robots and 'routine' work in the public sector'. *Industrial Relations Journal* 52:2: 109-124.

Løken, E., Stokke, T. and Nergaard, K. (2013) *Labour Relations in Norway*, Oslo: FAFO.

Lorenz, E. (2015) 'Work organisation, forms of employee learning and labour market structure: accounting for international differences in workplace innovation', *Journal of Knowledge Economy*, 6(2):437-466.

Lund, H and Karlsen, A. (2020) 'The importance of vocational education institutions in manufacturing regions: adding content to a broad definition of regional innovation systems', Industry and Innovation, 27(6):660-679.

LWI (Learning and Work Institute) (2021) *Disconnected? Exploring the Digital Skills Gap*, London: WorldSkills UK.

Martin, J. P. (2017) 'Policies to expand digital skills for the machine age', IZA Policy Papers Series, No. 123, Bonn: IZA Institute of Labor Economics.

Martin, J.P. (2018) 'Live longer, work longer: the changing nature of the labour market for older workers in OECD Countries', IZA Discussion Papers, No. 11510, Bonn: IZA Institute of Labor Economics.

Moniz, A. and Krings, B. (2016) 'Robots working with humans or humans working with robots? Searching for social dimensions in new human-robot interaction in industry'. Societies, 6(3):23.

Nergaard, K (2020) *Organisasjonsgrader, tariffavtaledekning og arbeidskonflikter* 2017/2018 Fafo-notat, Oslo: FAFO.

OECD (2004) *New Perspectives on ICT Skills and Employment*, DSTI/ICCP/IE(2004)10/FINAL, Paris: OECD.

OECD (2016) *Skills for a Digital World*, Digital Economy Papers, No 250, Paris: OECD.

OECD (2019a) *OECD Skills Outlook 2019: Thriving in a Digital World*, Paris: OECD.

OECD (2019b) *How's Life in the Digital Age? Opportunities and Risks of the Digital Transformation for People's Well-being*, http://www.oecd.org/publications/how-s-life-in-the-digital-age-9789264311800-en.htm

Orlik, J (2018) 'Four steps to define digital skills', London: Nesta/Readie, https://www.nesta.org.uk./blog/four-steps-to-define-digital-skills/

Pedan, M., Gregor, M. and Plinta, D. (2017) 'Implementation of automated guided vehicle system in healthcare facility,' *Procedia Engineering*, 192:665–670.

Pfeiffer, S. (2016), 'Robots, Industry 4.0 and humans, or why assembly work is more than routine work', *Societies*, 6(16):1-26.

Rivas, C. (2012) 'Coding and analysing qualitative data' in C. Seale (ed) *Researching Society and Culture,* Sage: London, 366-395.

Rolandsson, B., Dølvik, et al (2019) 'Digitalization in Nordic manufacturing: some case-study illustrations', Nordic Future of Work Project 2017-2020, Working Paper 3. Oslo: FAFO.

Thompson, P. and Laaser, (2021) 'Beyond technological determinism: revitalising labour process analyses of technology, capital and labour', *Work in the Global Economy* 1(1-2):139-159.

van Wanrooy, B., Bewley, H., et al (2013) *The 2011 Workplace Employment Relations Study: First Findings,* London: DBIS/ESRC.

Warnhoff, K. and de Paiva Lareiro, P. (2019) 'Skill development on the shop floor - heading to a digital divide?' Proceedings of the Weizenbaum Conference 2019 Challenges of Digital Inequality (pp.1-10) Berlin.

WEF (World Economic Forum) (2020) *Schools of the Future – Defining New Models of Education for the Fourth Industrial Revolution*, Geneva: WEF.

Wilson, A. (2013) *UK: The representativeness of trade unions and employer associations in the food and drink sector*. https://www.eurofound.europa.eu/publications/report/2013/uk-the-representativeness-of-trade-unions-and-employer-associations-in-the-food-and-drink-sector

Wolf, A. (2011) *Review of Vocational Education: the Wolf Report*, London: DfE.

Figure 1: Digital skill requirements in the case study jobs