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‘There’s A Machine On The Team’: Employers’ Perspectives On Graduate Employability In Digitised Workplaces

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‘THERE’S A MACHINE ON THE TEAM’: EMPLOYERS’ PERSPECTIVES ON GRADUATE EMPLOYABILITY IN DIGITISED WORKPLACES

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ABSTRACT

The implementation of interconnected digital and cyber-physical technologies across engineering fields is changing the nature of professional work. These new forms of work present both technical and social challenges; it is therefore timely to consider the implications of the digital transformation of work for engineering education. In this study the focus is on the technical and social skills that employers have identified as desirable for productive work practices in digital/cyber-physical environments. The research question guiding the study is: What technical and social skills do employers in digitised/cyber-physical workplaces value in engineering graduates? The study drew on Legitimation Code Theory’s Specialization dimension to reveal the

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underpinning principles of how technical and social skills are integrated in digital environments. Structured interviews with employers were analysed to categorise the technical and social skills that were highly regarded in environments that had implemented digital and related technologies. The study identified three levels of socio-technical integration valued by employers, namely: 1) enthusiasm for, and appreciation of, the role of digital and related technologies in addressing engineering and societal challenges; 2) teamwork and/or client support in digitised environments; and 3) interdisciplinary and transdisciplinary collaboration for digital and related technological innovation. The study identified an emerging shift from a skills discourse that assumes a separation between technical and social skills towards one that captures the dynamics of socio-technical integration in digitised and related technological practice.

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1 INTRODUCTION

1.1 Background, research problem and focus

Many workplaces are undergoing forms of transformation that can largely be attributed to the digitisation of work (Jensen, 2018). Implementing digital and related technologies in engineering work presents both technological and social challenges, described as the 'socio-technical evolution of the human role in production systems' (Frank et al. 2019). Thus, as well as transforming production and services through digitisation, employers face the challenges of recruiting, training, and supporting staff at both operational and managerial levels. The digital transformation of work consequently poses challenges for professional practice and engineering education. The problem that this study has identified is a mismatch between the technical and social skills required in digitised workplaces and the forms of knowledge and skills acquired in engineering education. The impact of advanced technologies on professional education is underrepresented in the literature, and it is this issue that this study addresses. The guiding research question for the study is: What technical and social skills do employers in digitised/cyber-physical workplaces value in engineering graduates? Although changes in machinery and technology are obvious, and have a direct impact on practice, the more challenging issue is to adapt 'the human side of the transformation to the new work settings' (Rangraz and Pareto 2020). Because digital technologies are often disruptive in nature, when they are put into practice, they necessitate the acquisition of new skills sets and mind sets. It is generally acknowledged in innovation studies that in order for technological innovation to be adopted, social innovation must first occur (Charalambous et al. 2017) yet 'worker-level factors explicitly aligned with emerging cyber-physical systems receive little attention' (Blayone and Van Oostveen 2020). In order to address this gap, it was necessary to draw on theoretical tools that could identify the principles underpinning the emergence of new engineering technical and social skills in digitised work environments and to consider their implications for engineering education.

1.2 Theoretical framing

The study required an analysis of changes in practices brought about through advanced technologies. The Specialization dimension of Legitimation Code Theory (Maton 2013) was chosen because it explains the nature of specialised practices. The principles underpinning practices were revealed using specialization tools to analyse varieties of technical and social skills. All engineering practices involve technical and social skills. Practices in workplaces will therefore always include technical and social dimensions because the accomplishment of engineering work involves tools and people.

Table 1. The Specialization Dimension

<table>
<tr><th colspan="2">Technical skills</th><th colspan="2">Social skills</th></tr>
<tr><td rowspan="2">Stronger
↕
Weaker</td><td>Technical skills are highly important for practice.</td><td rowspan="2">Stronger
↕
Weaker</td><td>Social dispositions are highly important for practice.</td></tr>
<tr><td>Technical skills are less important for practice.</td><td>Social dispositions are less important for practice.</td></tr>
</table>

Source: Adapted from Maton 2013.

Table 1 explains that technical and social skills could be stronger or weaker in different work practices. There are likely to be cases in which specialised engineering knowledge and technical skills are emphasised, as well as cases in which professional dispositions and social skills are more important. There are also likely to be work practices in which both technical and social skills are equally important. The relative strengths of the technical and social dimensions can change over time, particularly when new technologies are introduced into workplaces. Applying the specialization tools in this study revealed how employers conceptualised the appointment of new graduates in terms of their technical skills (e.g., qualifications in renewable energy technologies), and in terms of social skills in the work environment (e.g., a passion for cleaner sources of power).

2 METHODOLOGY

2.1 Research design

To address the research question, we interviewed senior managers involved in recruitment. In 'elite' interviews, interviewees are selected for their leadership roles and access to company information (Empson 2018). Because interviewees are often under pressure of time, the interview protocols should be short and focused (Aberbach and Rockman 2002). In addition, the interview protocol should be sufficiently opened-ended to enable the interviewee to structure his or her own account of the issue under investigation (Empson 2018). In this study, some interviewees were senior managers of large international companies, while others were owners of smaller businesses that operated regionally. We ensured that there was gender representivity, representation from the global South and the global North, as well as from start-up companies and more established companies.

Table 2. Interviewee matrix

No	Interviewee	Gender	Engineering	Scope	Position	Country
1	Atfa	F	Computer	National	Owner	Rwanda
2	Benicio	M	Electronic	National	Manager	Mexico
3	Chandrak	M	Chemical	Multinational	Division Head	India
4	Daniella	F	Construction	National	Partner	South Africa
5	Esther	F	Agriculture	Local	Owner	South Africa
6	Fadhili	M	Electrical	National	Owner	Kenya
7	Gary	M	Electronic	Multinational	Division Head	United Kingdom
8	Hans	M	Mechanical	Multinational	Division Head	Germany
9	Ivan	M	Chemical	National	Manager	Russia
10	Jean	F	Mechanical	Multinational	Division Head	United States
11	Karin	F	Construction	National	Division Head	Sweden
12	Lucas	M	Electrical	National	Division Head	Greece

The researchers studied information on the companies' websites, including job advertisements prior to the interviews. This prepared them for a focussed engagement with participants in the limited time available. The main question probed was: 'When you hire graduates for your company, are there particular qualifications and skills sets that you are looking for?' Prompts were used to probe the participants' responses, or to elicit more detailed explanations. Interviews were conducted on the Zoom platform and the interviews were audio-recorded, transcribed, and anonymised. Ethical clearance for the research activities was obtained from the lead institution, and informed consent was obtained from all participants. Consent to record the interview was obtained prior to the start of the interview.

2.2 Data analysis

There were two levels of data analysis: the first level required *in vivo* coding of the data (drawing on the actual words and descriptions of the participants); the second level required theoretical coding, drawing on the categories of Specialization that were adapted for this study (Table 1).

3 RESULTS

Employers valued a wide range of technical and social skills – from cutting edge digital technologies to interdisciplinary teamwork. The technical and social skills that employers valued are clustered into categories below, based on the *in vivo* coding.

3.1 'The digital tools of their jobs'

None of companies included in the study had fully developed their own technological systems and most employers expected engineering graduates to contribute to the adaptation and efficient use of the digital and other technologies that they had invested in. Employers valued graduates' technical engineering knowledge, and understood university qualifications to be indicators of these achievements. Chandrak, a regional manager of a chemical engineering company, expected chemical engineering graduates to 'have knowledge of quantum computing, AI, robotics, real-time data – the digital tools of their jobs.' Hans, the manager of an automotive engineering plant, expected graduates to be 'highly competent in automated production technologies.' University degrees were valued, even in companies that prided themselves on being 'artisanal', such as the brewery that Ivan managed. He explained that the implementation of automated processes increased the need for university graduates. As Benico, in a banking context, put it: 'We don't all need to be AI experts ... but we all need to have some of the skills that the AI environment demands' (Benico).

3.2 'Respect for the old ways'

In workplaces that traditionally employed artisanal workers, university graduates were expected to respect 'the old ways', even while having a 'passion for new technologies'. For example, engineers needed to 'respect' the traditional brew masters and had to answer to them. In the case of farm manager, Esther, agricultural graduates were expected to respect the practical knowledge of farm labourers as they had 'a lifetime of working with grape production and they [knew] things that a young graduate with a fancy degree [didn't] have a clue about.'

3.3 'Do their eyes light up?'

All the companies in the study had introduced digital technologies into their work practices, they therefore expected graduates to be enthusiastic about these innovations. Esther described 'ideal' employees as 'excited about the future, they love the tech – and they want to go places with us.' Karin was looking for graduates 'who are driven and committed to innovation and change in the building industry'. While participants wanted to hire graduates that would contribute to the company, they were also keen to find recruits who were passionate about the possibilities of advanced technologies. In the extract below, Atfa demonstrates the convergence of passion for the company, for the industry, and for advanced technologies:

> I can identify the person who will be able to contribute to our company's vision. I will usually ask a question about a new technology and wait for the response. The person whose eyes light up and can't stop speaking about it, well that's my next hire.

Several participants required new recruits to be 'passionate', not only about the new technologies, but about how these could be used, for example, to mitigate climate change. For Lucas, the ideal graduate 'must be driven by the environmental sustainability of wind generated power'. And if you are going to work in the brewing industry, as Ivan pointed out, 'it helps if you enjoy the product.'

3.4 'The digital twin'

Hans used the term 'digital twin' to explain a type of remote technical assistance in which the engineer had a digital twin of the machine supplied to a customer, who had the actual machine and connected digitally to the engineer or other operator, as if she or he was 'standing right next to them.' Several companies used digital technologies in similar ways. In the banking context Gary explained that the ‘exponential growth in the number of clients’ and the increasing ‘complexity of the services they required’ meant they were ‘changing from traditional personal banking and advising to harnessing the power of the new digital technologies, AI, data analytics, cyber security…’ Employers were looking for graduates who could work comfortably in these digital spaces.

3.5 ‘The last mile’

The term ‘the last mile’ was used to describe that part of the business operation that was not yet fully digitised or automated, as Fadhile explained: ‘it’s about pushing that digital environment further into the real environment’. In ‘the last mile’ advanced technologies were not yet available, thus basic technologies or traditional ways of marketing, installing, or implementing had to be used. For Chandrak, the last mile was the engineer in the field. Despite fieldworkers’ access to ‘drones and robots that augment their capacities [to] carry out many tasks in the pipeline that are too dangerous for a person to undertake,’ there remained a gap in which work was not yet automated and the fieldworker needed ‘to consult a senior engineer [and] obtain the necessary authorisations.’ For Esther, the last mile was that part of farm work that robotic harvesters and drones could not do: ‘robots can pick and the drones can scan but they don’t do the regular maintenance of the vines’. Addressing the ‘last mile’ usually involved employees using basic technologies in some areas of work.

3.6 ‘Everything’s connected’

The workplaces employed technologies that communicated with one another and connected people, machines, products, services, and systems. The nature of this interconnectedness was evident beyond the technical in the interdisciplinary nature of the work, the complexity of processes, and the diversity of work teams in terms of nationalities, gender, and educational levels. Installing wind turbines, as Lucas explained, was ‘the end point of a very long process [and] expertise and experience at all the stages of the process’ were needed. Inter-disciplinary and inter-professional collaboration has always characterised workplaces that employ university graduates, however what was notable was the increasing hybridity of workplaces, in particular the extent to which human-machine interactions had become commonplace. Esther’s description of how farm workers accepted robotic harvesters is a case in point:

> … they had training in working alongside the robots … a couple of years down the line they are a lot more comfortable with them … I heard our foreman explaining the situation to some new staff ... he told them that [there’s a machine on the team] [translated from Afrikaans] ... and they were ... ja well no fine.

The introduction of advanced technologies in Karin’s building company saw ‘a change in professional roles’, in particular a role reversal between architects and builders, while the introduction of automation had the unexpected, but welcome, effect of bringing more women into construction: ‘We have used machine strength to make the workplace more equitable’ (Karin).

3.7 Discussion

The study identified three levels of technical skills valued by employers: 1) the use of non-specialised digital technologies (often for communication); 2) the use of advanced digital technologies to accomplish work; and 3) the design and development of advanced technologies associated with Industry 4.0, such as robotics, artificial intelligence, the Internet of Things, cloud computing, and so on. The study also identified three kinds of social skills in companies that used the technologies associated with Industry 4.0: 1) Some changes in personal dispositions and interpersonal relationships, 2) more complex changes in the ways in which work was accomplished, and 3) the transformation of workplace relationships.

As new technologies entered workplaces, the need for technical engineering knowledge increased, for example, the artisan brew masters were trained to use scientific data to confirm or develop their brewing abilities. Although disciplinary knowledge was not always required to use specialised digital technologies, the need for technical skills strengthened when specialised digital technologies were introduced, and training was usually required (Table 3). An example is the chemical engineer using a specialised robot to inspect an area of a pipeline. Operating the robot required training in advanced technical skills, beyond the engineer’s specialist rheology knowledge. At the highest level, engineering knowledge for the design and/or adaptation of specialised technologies was valued. None of the companies included in the study had designed their own digitised systems, but most companies expected that graduates would contribute to their adaptation and efficient usage.

Table 3. Emerging socio-technical integration

Socio-technical	**Description**	**Example from the data**
Level 3	Graduates collaborate in interdisciplinary and transdisciplinary teams to innovate in interconnected digital and cyber-physical environments.	I want to see these young engineers telling us about future directions of technology (Chandrak).
Level 2	Graduates work comfortably with colleagues and clients in a digitised environment.	... for our customers it's as if the [Name of Company] operator is standing right next to them ... so the operators need to understand and anticipate the needs of the customers ... and it all starts with the digital twin (Hans).
Level 1	Graduates value the ways in which digital and related technologies can address engineering and societal challenges.	They must know about the range of technologies that we work with - and how we can reduce our carbon footprint … from planning to building to occupation and sustainability into the future (Daniella).

The use a robotic pipeline inspector did not change the need for a junior engineer doing fieldwork to consult with senior engineers, although the mode of consultation changed considerably. The field inspector could send digital images to the senior engineer, rather than return to the office for a face-to-face meeting (Level 1). Some work practices changed more noticeably. For example, in the automotive foundry both specialised and non-specialised technologies were used. Digital twins were made possible by the images produced by specialist machines, but non-specialised digital technologies (e.g., mobile phones or tablets) were used to connect remote operators with clients (Level 2). In some cases, digital technologies involved considerable changes in professional skills and the disruptions of social hierarchies. For example, the use of robots in the construction company enabled more women to enter the construction field (Level 3).

3.3 Conclusion: What do employers value in graduates?

In addressing the research question 'What technical and social skills do employers in digitised/cyber-physical workplaces value in engineering graduates?' the study identified three broad domains in which the integration of socio-technical skills emerged: 1) enthusiasm for, and appreciation of, the role of digital and other advanced technologies in addressing engineering and societal challenges; 2) teamwork and/or client support in digitised environments; and 3) interdisciplinary and transdisciplinary collaboration for technological innovation.

Many of the findings of this study are supported by the literature. For example, the increasing need for technical skills in digitised workplaces (Jensen 2018). In the literature, 'respect for the old ways' includes enduring professional skills and values, such as 'emotional intelligence, empathy, altruism, and reciprocity' (Aoun, 2017). The literature also supported some of the more specific findings on the importance of new graduates' 'enthusiasm' for new technologies (Rangraz and Pareto, 2020). While the existing literature implies that workplaces with digital and other advanced technologies will impact professional practices in many ways (Frank et al. 2019), these have not always been specified or studied in-depth. This study has contributed to an understanding that social skills are not 'added onto' technical skills but are deeply integrated with them.

This study contributes a theorised account of the technical and social skills that employers value in engineering graduates entering into their industries. In particular, the study contributes to a deeper understanding of the interconnections between digitised work practices and the cultivation of social skills and dispositions. The employers highlighted a need for stronger university/industry collaboration in engineering education. Atfa provided a rationale: 'We are trying to build this industry and [universities] are producing the professionals for this industry, so obviously we must work together'. Some participants felt that in many ways engineering practice was ahead of engineering education. Other participants wanted to bring theory and practice into a space of mutual learning. Several of the interviewees clearly valued engineering qualifications but tried to explain the particular combinations of scientific knowledge and social dispositions that they felt made a difference to the employability of graduates. As Atfa put it: 'there is a false dichotomy between soft skills and hard skills'. The study highlighted employers' perspectives of how particular integrations of technical and social skills enabled graduates to successfully transition to practice in digital environments. While more detailed studies of how digital and cyber-physical technologies impact engineering practice in specific fields and industries are needed, the study points to gaps between practices in digitised environments and engineering education. The results thus have implications engineering educators. In particular, the study identified an emerging a shift from a skills discourse that assumes a separation between social and technical skills towards one that captures the dynamics of socio-technical integration.

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