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Stephen Billett, Education and Professional Studies, Griffith University, Australia

Competence in contemporary working life requirements is increasingly aligned with electronically mediated tasks and work roles: i.e. the digitalisation of work. This alignment necessitates workers learning and utilizing the conceptual knowledge and ways of working needed for this work. This knowledge is often distinct from and displaces workers' existing ways of knowing, which threatens their competence and sense of self. Yet, it can be difficult to access, learn and practice, requiring it to be mediated through interventions making it knowable. For working age adults, this often needs to occur through work activities for efficacy and practical reasons. These worklife learning issues are discussed here from a cultural psychological perspective, drawing on studies of contemporary work and human cognition, considerations for how these forms of knowledge can be made accessible and their processes of knowledge construction be supported. Four key propositions are advanced: i) this knowledge needs to be made accessible to be engaged with and learnt; ii) that can often best occur in work settings iii) workers' occupational subjectivities need accommodating and iv) electronically-mediated forms and artefacts offer means to make that knowledge accessible and support its learning. Hence, learning, work and digitalisation are reciprocally aligned in promoting both the initial and ongoing development of workers' capacities.

Keywords: lifelong learning, conceptual and symbolic knowledge, procedural knowledge, digitalisation of work, pedagogic worth of artefacts, worklife learning, mediation

Bio notes
Stephen Billett is Professor of Adult and Vocational Education in the School of Education and Professional Studies, Griffith University, Brisbane, Queensland Australia. His research interest are in learning the capacities required for paid work, through experiences in and across working life, educational institutions and their integration.

Contact: Mount Gravatt campus, 4121
Queensland, Australia
Email: s.billett@griffith.edu.au
Phone: +61 (0)7 3735 5855 (please use email as working off campus because of CoVid19)

What is already known about this topic
- The knowledge required for work constantly changes
- Digitalised work has changed the requirements of much work and many occupations
- Conceptual and symbolic knowledge are required for competence in digital kinds of work

Many studies have illustrated the impact of digital technologies across a range of occupations and industry sectors

What this paper adds
- An elaboration of how the knowledge to be learnt and ways of knowing have changed in digital work
- Considerations of the implications of the changes for worklife learning (lifelong learning)
- The importance of digitalised artefacts mediating access to this knowledge through symbolic representations

Implications for practice and/or policy

- Working age adults need to be able to access the kinds of knowledge required for digitalised work
- Worksites and work practice are potentially the optimum circumstances for accessing and learning this knowledge across working life.
- The ability of this knowledge to be represented symbolically is a key basis for workers ongoing learning of digitalised work requirements.
- Digital technology offers means for the conceptual representations to be made accessible

> "… hardly have we approached the problem of understanding the intellectual impact of the printing press than we are urged to confront the psychological implications of computerisation." (Scribner, 1985): 138)

Accessing and securing the conceptual knowledge

The proposition that Silvia Scribner advanced in the mid-1980s was prescient and insightful (Scribner, 1985). It reminded us that across human history cognitive processes are both enabled and developed further through workers' engagement in and mediation of both the material and symbolic elements of work activities. And, as these elements are subject to change, so too are the personal and socially-derived mediational means through which we need to engage with and mediate our learning of these activities. It was also prescient as it alerted us early to the cognitive consequences of changes in work brought about by digital technologies. These changes have brought concerns about how work activities that increasingly rely on digital and symbolic forms can be accessed and learnt (Harteis, 2018a; Poquet & De Laat, 2021; Suchman, 2016). There is reciprocity within these changes, however. The knowledge required to use and to realise the purposes of these technologies are dependent upon its means of operation being learnt, including understandings about it and procedures for its enactment. This includes workers who are required to learn about and adapt to this new technology across their work lives (Wallin, Pylväs, & Nokelainen, 2020). So, rather than privileging considerations of either the person or the technology, the relations between them are salient (Suchman, 1997). Scribner also spoke directly to the issue of digitalisation and ongoing worklife learning (i.e. lifelong learning). Her seminal investigation into the impact of the introduction of computer numerically controlled (CNC) lathes in metal-machining illuminated the cognitive consequences of changes in technology for metal machinists, and, in particular, the shift to symbolic forms of knowledge, knowing and doing (Martin & Scribner, 1991). It also highlighted bases of these workers' occupational competence were challenged by this new technology. Workers' ways of knowing and doing arise as legacies of their work experiences over time (Harris, 2007) and intentionality (Malle, Moses, & Baldwin, 2001). They are premised on engaging in, being selective through and monitoring of goal-directed activities at work that also shapes their subjectivity (i.e. how they view themselves as workers) (Billett, 2011). Prior to the introduction of CNC technologies, metal machinists operated lathes manually guided by their sensory processes. These workers' skills and subjectivities were premised on their manual control of lathes. They would feel the vibrations as the tools they controlled by turning dials cut into the metal and guided the bite and pressure of the tools, as did the smell of the coolant evaporating as it hit hot metal, noise made by the tool cutting into the metal and the colour of the swarf (i.e. waste metal) as it peeled away from the turning metal. All these sensory inputs were essential for these lathe's manual operation and they had been learnt and honed through lengthy practice in achieving right diameters, finishes and smoothness of metal being machined. They would also use callipers and other visual measuring devices to guide the amount metal they were cutting away to meet the specifications for the components they were machining. So, although central to these machinists' occupational competence and subjectivity, these forms of knowledge and ways of knowing were rendered partially redundant by CNC technologies as they were displaced by digital processes.

Instead, numerical codes and values were entered into the computers to pre-program and guide automated tools to precisely produce metal components. So, the machinists' role changed from manually operating lathes through sensory and haptic processes to programming a computer and minder of lathe operating in pre-programmed ways (Martin & Scribner, 1991). More than developing new knowledge and ways of knowing, there were challenge to these machinists' sense of self. The 'pride of trade' associated with operating a lathe was now displaced by digitalization. This seminal investigation highlighted impacted that have subsequently been rehearsed.

Abrahamsson (2006), for instance, noted that Swedish tin miners' skills and subjectivities were confronted by changes to underground mining. Their work changed to be largely undertaken by remotely controlled drills and digging machines operating underground that were remotely controlled from above ground. More than learning to use new technology to remotely operate the mining equipment, these miners were confronted by challenges to subjectivities associated with masculine work (Somerville, 2006). Even in controlling the mining equipment when working in an office above ground, they still wore their mining clothes to sustain their sense of selves as miners (Abrahamsson, 2006). Similar changes in work requirements and challenges to subjectivities were identified when truck drivers had to adapt to highly automated driving and vehicle management systems based arrays of digitalised information on the dashboard (Lewis, 2011). Again, these workers' competence had been founded in sensory processes that informed and made gear changes based on engine vibrations felt through their feet and their seat and through listening to the truck's engine. Now, they had to use information from a visual display while sitting in a shock-absorbing seat in a sound-proofed air-conditioned cab. This physical and sensory separation compromised their ways of knowing about operating the vehicle: the demands being placed upon the engine, and timeliness of gear changes and braking. Preferring their existing ways of knowing, some drivers left windows down to hear the engine and inform decisions about gear changing and braking (Lewis, 2011). Such responses can be easily dismissed as workers' resistance to change. It may be more than that. Airline pilots reported that the change to fly-by-wire controls over manual controls on commercial airliners' ailerons, flaps and elevators led them to lack a sense of controlling these planes. This concern led to the introduction of haptic technologies enabling pilots to sense and appraise the stresses and strains being placed upon planes during flights. Also, it was found that control room operators' lack of knowledge of a nuclear power plant's operations limited their ability to respond to problems in its cooling system with almost catastrophic consequences (United States Nuclear Regulatory Commission, 2004). There are undoubtedly many other such examples. The central concern here is that workers need to access, engage with, and learn new ways of working and how they mediate and learn from what they experience. Interacting with new technologies and developing understandings on processes founded on abstracted and opaque conceptual knowledge can be particularly difficult. When they cannot be experienced directly (e.g. through sensory processes), they may need to be mediated in different ways to make those knowledge and processes accessible. Effective mediation of this knowledge is central to workers' ongoing worklife learning (i.e. lifelong learning) and their subjectivities as working age adults (Wallin et al., 2020).

This article discusses how the capacities required for digitalised forms of work can be learnt and developed across lengthening working lives. It is proposed that considerations for providing working age adults (i.e. those old enough to work and have not retired) with access to understandings about, conceptions of and the procedural aspects of these digitalised forms of work and work performances (Poquet & De Laat, 2021). Moreover, educative support, albeit in workplaces or tertiary institutions need to acknowledge and address issues of workers' subjectivities in developing these capacities. In many cases, the processes of supporting and guiding this development (i.e. lifelong education) will be require enacting at work and through work practices. In making its case, the following structuring and presentation of text is advanced. The four issues comprise of: i) accessing and securing conceptual knowledge, ii) redressing workers' subjectivity, iii) providing learning experiences through work practice and iv) the utilisation of digital technologies to assist this learning.

Accessing and securing conceptual and procedural knowledge

Within seminal socio-cultural and cognitive constructivist accounts of learning and development, individuals' construal and construction of knowledge (i.e. learning) is premised on an ability to access and generate representations of that knowledge. In social and cultural constructivism and cultural psychology, this is referred to as inter-psychological processes (i.e. those between the person and the social world 'beyond the skin' (Wertsch & Tulviste, 1992) that leads to an intra-psychological legacy in the form of new or changed knowledge structures (Wertsch, 1991). Vygotsky is held to have preferred the terms inter-mental and intra-mental (Wertsch & Tulviste, 1992), proposing that something needs to be experienced on the social plane (i.e. inter-mentally) prior to being construed and constructed within the person (i.e. intra-mentally). However, the individual requires intra-mental capacities for that experiencing. So, inter-psychological or inter-mental processes are premised on individuals' directly or indirectly being able to access (i.e. experience) what is being suggested by the social world, albeit mediated by text, artefacts, sensory or symbolic forms. But, as illustrated in the studies of CNC lathe operators, truck drivers and pilots, much of the knowledge required for digitalised work is not easily represented and/or directly accessible and, therefore, learn. Without that access, the inter-psychological process of experiencing can be partial, compromised, or erroneous. For instance, in mediaeval times, when flies were seen coming out of overripe fruit, it was assumed this was a natural process of metamorphosis (e.g. rotting fruit turned into flies). These observers did not understand that eggs that had been planted under the skin of the fruit and larva were feasting before becoming flies. So, without understandings and access to how these technologies operate, it is difficult for that knowledge to be engaged with and appropriated by workers. So, just as text can be read and its meaning mediated by individuals, similar mediational processes need to occur inter-psychologically through other forms of sensory engagement (e.g. haptic, aural, visual). Yet, the conceptual knowledge that is central to understanding digitalised processes and digitally driven forms of work tasks may not be accessible through the kinds of sensory processes that much of working knowledge has been acquired.

As this knowledge is often opaque and abstracted from practice, and not directly experienceable, it may need to be represented in some way for workers to construe and construct it (i.e. learnt). For instance, visual representations of the COVID-19 virus have been created to assist people in understanding its structure and how it is transmitted and can be controlled, whereas other health-related knowledge might be acquired through direct observation of patients, listening to heart murmurs, visual examination of cuts and sores, et cetera. For instance, learning the process of auscultation (i.e. using stethoscope to listen to sounds within the body when diagnosing patients' health) has been augmented through the use of assigning names to the sounds. Rice (2010) reports using of familiar names that medical students would remember to describe the sounds made by heart valves. For instance, the word 'New York' was used as a simile for the sound made by a heart valve not quite closing. These mnemonics provided bases for reminding and recalling that sound and the heart condition it indicates. With the kinds of sensory processes comprising manual lathe operators' expertise being displaced by numerical coordinates, it becomes necessary to find ways of assisting these operators develop these new ways of knowing when they are distinct from those they currently possess and cannot be directly experienced.

Consequently, these changes are more than different representation of the knowledge as a conceptual challenge, but also understanding new processes of manufacturing metal components (i.e. procedural knowledge). This is not to deny that the machinists bring a range of important insights, understandings and practices, including their particular kinds of mathematical knowledge, but there are specific and distinct ways of knowing and procedures with which they need to become competent. Hence, finding ways of representing these forms of knowledge, so that they can be construed and constructed inter-psychologically to become intra-psychological qualities is important. This is a key challenge for supporting the worklife learning of many kinds of workers as forms of work processes are rendered abstracted and procedures are not observable or can be otherwise

monitored through immediate sensory input. For instance, the use of augmented reality has been shown to assist develop such understandings that might not be directly accessible in clinical settings (Moro, Phelps, Redmond, & Stromberga, 2021), and also immersive engagement through technologically-mediated medical scenarios and problems (Reilly, Kang, Grotzer, Joyal, & Oriol, 2019)

It follows that to make these kinds of knowledge accessible, we need to find ways of representing them. Yet, there is nothing particularly new here. As foreshadowed, when abstracted kinds of learning have been required to be learnt, there is a long and extensive history of using representational means to mediate access to this knowledge. Anthropology offers examples of such processes through the mediating qualities of artefacts. The learning to navigate by Micronesian fishermen by learning star patterns was mediated through the use of stones on the beach that represented these stars and in other circumstances through means to measure and calculate (Pelissier, 1991). Indeed, text and symbols have long been used (e.g. words, tokens and figures) and language and representational forms of these have become quite commonplace within computers and electronic technology (e.g. icons). It is the appropriation of these symbols that become the intra-mental or intra-psychological constructions that permit individuals to recall and utilise the knowledge required to fulfil these tasks.

So, making accessible knowledge that is rendered opaque or otherwise abstracted from engagement by workers is a worthwhile project.

Redressing issues of workers' subjectivity

The digitalisation of work, as foreshadowed, can represent threats to workers' sense of self and, consequently, the level and kind of engagement with these new technologies and their readiness to engage and learn. Readiness to learn is more than having prerequisite knowledge to engage in that learning (Billett, 2015). It includes whether individuals are interested in engaging in the effortful process of learning new forms of knowledge. The ongoing development of workers' occupational capacity across working life (i.e. lifelong learning) means they may have to discard elements of what they know, can do and value upon which their occupational sense of self rests and embrace new ways of knowing, doing and valuing. For instance, Lewis (2011) noted, that many of the truck drivers he interviewed would be classified as older workers and their driving skills arose from extended experience with manually-controlled trucks in which sensory processes were essential for braking, changing gears and controlling the vehicle. Hence, it was necessary to engaging the driver in the effective use of the truck's computer systems and use of display systems in ways that they could optimise fuel consumption, manage emissions and drive safely and within the vehicles' parameters. So, finding means by which these drivers could become oriented to the vehicle's computerised systems was be essential. Most likely, through success in operation commitment and persistence with engagement arises.

Yet securing that commitment can represent a significant challenge for these individuals and warrants pedagogic processes be adopted to support and assist these workers learn how to engage with and develop the capacities to utilize these technologies. For instance, Wertsch (1998) refers to elite pole vaulters who were rendered uncompetitive by the introduction of more flexible aluminium poles that required a different technique than those used with bamboo poles. Consequently, more than accommodating something unfamiliar, there specific kinds of capacities were required to be learnt. This may well be the case with new technologies, such as arising through the digitalisation of work. This will need to occur in ways that can sustain workers' sense of self as working age adults for whom their occupational competence is central to their subjectivity. Commitment to new work processes is most likely to arise when individuals become competent and confident with them (Mclaughlin & Marsh, 1978). Noteworthy here was that in this classical study of outcomes of educational interventions, unless workers (e.g. teachers) had developed the competence to use new strategies by the time support was withdrawn, they were unlikely to adopt and utilise the innovations that were the object of the interventions. These different kinds of commitment can be seen as what (Wertsch, 1998) refers to as appropriation, rather than the mastery of knowledge.

Appropriation is personal commitment that leads to full-bodied engagement with what needs to be learnt, whereas mastery is superficial engagement to meet the approval of others, albeit underpinned by a lack of commitment. The evidence suggests that workers' positive response to changed work requirements and task performance is likely to be the strongest when they are able to use the change processes to be more effective in their work (Billett, 2012) and also be involved in their initiation (Billett et al., 2018).

When working in the garment manufacturing industry, I witnessed the introduction of needle positioners and thread trimmers on industrial sewing machines that required some new skills to operate effectively. Initially, the machinists were reluctant to use these machines and cautious about their engagement in using laboursaving devices such as these positioners and thread trimmers. In the very public environment in the production line, these workers did not want to appear to be incompetent. To assist develop competence with these technologies, they were provided with opportunities to practice on exercise pieces printed on sheets of interlining. This allowed them to develop the control skills associated with positioning the needles (i.e. up or down) and activating the thread trimmers. Once competent with these new technologies, they embraced them as part of their everyday work and this was reinforced when their productivity was enhanced and the number of body movements they required, particularly in controlling the machines clutch, were reduced. However, the intervention that provided the machinists with the competence and confidence to utilise these technological-assisted work practices that developed their commitment to them. Even in terms of efficacy, it is noteworthy that as Darrah (1996) reported when production workers in a computer assembly process were not provided with adequate instruction and training on how to use the diagnostic equipment, their processes were inefficient and, in part, unnecessary and redundant. Yet, when they received specific instruction on how to effectively utilise the equipment, they became competent with them and were able to manage more effectively their complex work and checking processes. That is, when they were provided with new sets of skills that allowed them to be more effective, monitor the quality of their work and organise their production more efficiently, they appropriated and engaged effortfully with this technology. All this suggests it is important that workers be provided with opportunities to become competent with new technologies and through that opportunity and competence then become committed to that technology and its use. That is their subjectivity as workers were extended to these new technologies through the mediation of being adequately prepared to be successful in their use. So, more than an orientation to these technologies, is the development of capacities to successful adopt and use them (Poquet & De Laat, 2021). This imperative is addressed in the following sections.

Mediating learning within work practice

Much of the development of workers' capacities for effectively conducting digitalised work across their working lives will need to occur within and through their work practice. As Hamalainen, Lanz, and Koskinen (2018) note, traditional teaching methods will have limited efficacy for developing manufacturing employees' competencies. There are both pedagogic and practical reasons why the development of workers' conceptual and procedural knowledge for this work will most likely need to be generated within or at least as part of work activities and interactions (Harteis, 2018a). Pedagogically, for them to be effectively learnt it is necessary to make explicit and find ways of representing these forms of knowledge, and in ways that can be embedded or aligned within work practice, rather than being separate from them. In the contemporary era, this kind of learning has been viewed as being best developed in hybrid learning spaces (i.e. classrooms) and through specific educational interventions and by teachers (Diakidoy & Kendeou, 2001; Limon, 2001). Yet, even in these circumstances, there is often a need to use explicit examples or analogies to make accessible to those who are seeking to learn that knowledge what cannot be experienced directly. The rich indexicality properties of work practices and work activities (Anderson, 1982; Ericsson & Simon, 1984) and the physical and social contributions of workplace settings support processes of cognition, and the organisation and recall of cognitive structures (Lave, 1990; Lave, Murtaugh, & de la Roche,

1984) assist easing the demands of activities requiring higher cognitive functions (Glaser, 1984; Glaser & Bassok, 1989). So, rather than being neutral social and physical environments in which activities and interactions occur, workplace settings are deeply informative and support access to, ordering and engagement with what has been experienced (Barsalou, 2003; Goodyear, 2021). The qualities of 'classroom' activities and educational settings are configured in different ways than the circumstances of practice and the legacies of engaging in them (i.e. what is learnt). This often leads to failure to translate or transfer to other social and physical circumstance as how they are experienced and constructed in the settings in which they are learnt does not prompt recall or applicability in other kinds of settings where that knowledge needs to be applied (Billett, 2021). That is, their recall is hampered by differences in physical and social settings. Having learning experiences in the kinds of settings and embedding them in work activities where that knowledge will be deployed stands to minimise the difficulties of what is referred to as learning transfer (Lobato, 2006). When the processes of knowledge construal and construction occur in physical and social settings distinct from those in which the knowledge needs to be applied, that learning may not be readily applicable to the requirements of other circumstances. For instance, we know that much of classroom-learnt knowledge fails to adapt to other circumstances (Raizen, 1991). This lack of adaptability is premised on how the learners have construed and constructed the knowledge makes it less readily able to be recalled, applied and used effectively in other kinds of circumstances. Technologically mediated interactions in healthcare have been shown to assist address these issues in the on-going development of practitioners' knowledge through collaborative engagements characterised by active and scaled engagements for workers who are socially and geographically separated (Treasure-Jones, Sarigianni, Maier, Santos, & Dewey, 2019).

Also, regardless of where the experiences occurring, explicit strategies may be required to assist accessing what learners will find is difficult to be learnt through discovery alone. So, strategies such as direct explanation, analogies, the use of artefacts, representations of concepts and procedures are likely be required to achieve these learning outcomes (Ley, 2020). Accessing this knowledge may also require support and guidance from more informed interlocutors. Across human history although most workers have been expected to learn their occupational practice actively and independently in and through work (Billett, 2014). Yet, there have always been instances where interventions by more experienced practitioners have been necessitated, when the knowledge is hard to learn. Examples include the use of stones on the beach to assist Micronesian fishermen learning to navigate at night (Pelissier, 1991), blacksmithing in Africa (Lancy, 1980), birth attendants in Yucatán learning through stories and narratives (Jordan, 1989), experienced potters placing their hands over those of novices to assist them getting the feel for shaping pots on the wheel (Gowlland, 2012; Singleton, 1989) and experienced lace makers assisting novices learning how to hold multiple needles when producing complicated lace patterns (Makovichy, 2010). In all these instances, there is a combination of active learning, supported by insights, artefacts or direct support provided by a more knowledgeable interlocutor. Efforts to replicate workplace activities and interactions in education institutions are welcome and sometimes effective for initial occupational preparation. But may still lack the authenticity of the social and physical environments of workplaces and authentic bases for engaging and learning through work activities. For instance, initiatives such as hybrid learning experiences in Dutch tertiary education institutions (Zitter, Hoeve, & de Bruijn, 2017) are helpful means of providing initial occupational preparation as are those enacted earlier through learning factories (Hamalainen et al., 2018). However, these kind of experiences like other forms of none-high fidelity simulations whilst helpful, are incomplete because they may not provide access to learning through work-related activities. So, it is not a question of either formal instruction or learning through practice, but a combination of these experiences (Pelissier, 1991). For learning of digitalised work capacities across working life, this combination of experiences needs to be accessed through work.

So pedagogic practices aligned with work activities and interactions are likely to be required to secure access to knowledge such as the conceptual and procedural requirements of digitalised

work that are difficult to access or discover unaided. This means that standardised instructional processes offered through educational institutions and programs may not be optimum as the specific requirements for accessing these forms of knowledge across working life. Consequently, workplaces or work practices are likely to be the circumstances for much of this development, and that the pedagogic practices supporting it will likely be quite specific to the specific work practices.

Beyond their pedagogic imperatives, there are also pragmatic imperatives about the need for the capacities for digitalised work to be learnt in and through work. Workplaces and work practices are likely to be the key and only circumstances for developing much of this kind of knowledge across working life (Ley, 2020). This is because: i) the kinds of knowledge needing to be developed are equipment, artefact and workplace-specific, by degree, and ii) that many workers will not be able to be released from work for this development, even if it were available through educational institutions. Increasingly, across a whole range of fields of practice there is a growing push for continuing education/professional development to be conducted within workplaces and through work-related activities (Ley, 2020). The educative provisions supporting these developmental experiences need to arise through: i) engagement in and responding to the imperatives of practice, ii) being situationally prescribed, by degree, and iii) accommodating the breath of workers' readiness to access and engage in these kinds of experiences (Goodyear, 2021). These requirements suggest that educative provisions most likely need to be enacted within the workplace, and adjacent to productive activities towards which the learning and development is directed (Poquet & De Laat, 2021).

All of this suggests that workplaces seeking to: i) sustain the employability of their workforces, ii) maintain workplace viability and competitiveness in the provision of goods and services subject to constant changes in their requirements and iii) for developing forms of knowledge specific to the enterprise's operation may need to include the development of employability as a key element of business strategy. In essence, these workplaces need to become learning practices (Billett & Newton, 2010). Such a practice seeks to optimise learning experiences in and through work and as part of everyday work activities. Here, the central concern is that practice pedagogies that seek to develop understanding, and specifically, the development of conceptual and procedural knowledge required for engagement in digitalised work. As noted, these pedagogic practices can include storytelling, verbalisations, guided learning, the promotion of heuristics and mnemonics and providing direct guidance by more experienced workers who can use explanations, diagrams, and questioning to mediate the development of knowledge which is not directly accessible to the worker (Billett, 2001). In terms of learning through digitally mediated processes, it is suggested that there is a direct correlation between employees' engagement in the use of social media and forms of interaction and their learning (Ang, Orozco, Gijbels, & Van den Bossche, 2018). Hence, embracing these media through utilising online and digital processes for work-related communications, interactions and practices may promote enhanced and more frequent engagement with these kinds of technologies (Littlejohn, Jaldemark, Vrieling-Teunter, & Nijland, 2019), and, therefore, mediated learning for all kinds of classifications of workers. It is the readiness to engage with these media that may well lead to enhance learning experiences through digitalised representations and presentations. This engagement seems particularly important for ongoing work life learning for employees, such as those mentioned earlier, whose initial ways of knowing, unsurprisingly, did not include these kinds of technological mediation.

In all, basing developmental experiences in and through work offers both pedagogically and pragmatically sound means for supporting the on-going development of the knowledge required for digitalised work. The PIAAC findings indicate the efficacy of more informed workers providing pedagogic support and guidance through everyday work practices for technologically-rich work activities (OECD 2015). Also, having appropriately skilled educators from tertiary education institutions provide these experiences and guidance in workplaces to developing these capacities can augment the capacities available in workplaces. These options suggest focusing the development of these kinds of knowledge on and through the work practices or workplaces. It is in these

circumstances that the knowledge needing to be accessed can be made explicit or embodied in practice either directly or through the mediation of symbols, or other forms of representations. Moreover, the technologies that need to be learnt about can also provide access to these forms of knowledge, as discussed below.

Using digital technologies to mediate learning

There is nothing particularly new about technologies being used to mediate knowledge and its learning. The provision of writing, and technologies associated with preparing and using text exemplifies the need for capturing the knowledge to be learnt and its mediation, as one that evolves to accommodate changing needs. As noted, anthropological studies indicate that, historically, whilst much of the mediation enacted by workers themselves, mimetically (Billett, 2014), mediational means has been provided by artefacts, observation of practices and even direct interaction when the knowledge needing to be learnt cannot easily be accessed (Singleton, 1989). Above, examples of those kinds of mediations have been provided. However, for some time, and increasingly, digital technologies have the potential to make accessible knowledge that otherwise is difficult to represent and capture. Bedside computer systems provide healthcare staff with visual images of patients' pulse, blood pressure et cet era., making these accessible and comprehensible. The use of oscilloscopes allows students to identify and imitate tones in learning foreign languages, and Google translate can be used to improve pronunciation of words and languages. The tuning of musical instruments has been made easier and more informed by electronic tuner that indicates visually the closeness to pitch. Then, there is the use of simple artefacts such as checklists that are used in healthcare (Teodorczuk & Billett, 2017) and aviation (Kikkawa & Mavin, 2018; Mavin, 2016) to ensure effective practice, and means for healthcare workers can work and learn collaboratively (Treasure-Jones et al., 2019). These technologies provide pedagogic means for practitioners engage and learn the changing requirements for occupational practice across working lives (Goodyear, 2021). All of these artefacts have provided ways of mediating knowledge required for and arising through practice that can become embodied within the workers who engage with them (Ingold, 2000).

So, just as manual lathes, and controlling aeroplanes and trucks promoted inter-psychological processes through which workers could come to know, understand, and operate them through sensory processes, digital technologies offer the same and possibly greater potential, albeit in different and more effective ways. Given how the knowledge needing to be learnt to operate computerised lathes, fly by wire planes and highly automated trucks, can be represented, these kinds and means of representations are likely to permit access to and mediate process of individuals embodying this knowledge. These kinds of representations can be enabled through visual forms and even animations offer such mediational means. These means are exemplified by high fidelity simulators used in the training and certification of commercial airline pilots. These simulators have the capacity to represent the requirements for flying these planes and the knowledge and knowing required by competent pilots to be projected, experienced, and construed by these pilots. Issues of engagement are as important as what is afforded by the simulator, that is, how the pilots come to engage with them (Kikkawa & Mavin, 2018). An offhanded comment made by an experienced pilot (i.e. a captain) about being surprised with the amount of updraught when taking off from a particular (i.e. simulated) airport indicated that this technology generating what were perceived to be authentic kinds of experiences. It also indicated that the pilot was engaged in a full bodied and embedded way (Mavin, Kikkawa, & Billett, 2018). Whilst knowing he was in simulator, the perspiration marks on his back and under his arms indicated that this pilot's thinking and acting was embedded within practice. Whilst the costs and availability of such high-fidelity simulators restrict their use to occupational fields where mistakes can have catastrophic consequences (i.e. aviation, health, military), their pedagogic worth is revealed here. The key point here is that many of these digital technologies have interfaces and displays that can be used to mediate access to the knowledge required to be learnt to effectively utilise these technologies (A. Reilly & Spratt, 2007). Hence, the reciprocity between the person and the machine (Suchman, 2016) is evident here in their

learning, not just their operation. These are just the contemporary mediational means perhaps offer advances upon earlier forms of these means that were employed by machinists, nurses, truck drivers and pilots.

Of course, even with these, there are no guarantees. It has been noted that even the most authentic of simulations cannot necessarily prepare military personnel for the actualities of combat (Chatham, 2009). Nevertheless, simulations can provide access to understanding processes such as manufacturing which otherwise would be difficult to access (Hamalainen et al., 2018). As has been noted, the growing availability of on-line technologically mediated processes provide a growing range of ways that electronically-mediated means can assist the development of the knowledge required for digitalised work (Ley, 2020; Poquet & De Laat, 2021; Wallin et al., 2020).

Managing worklife learning in an era of digitalisation

In conclusion, it has been noted that work tasks that are reliant on digital technologies, and the conceptual and procedural knowledge that underpins their operation are likely to be become more widespread and required by all kinds of workers across their working lives (Nørgård, 2021). These are now and will in the future be widely adopted and become essential elements of work performance (Hamalainen et al., 2018; Harteis, 2018b). Therefore, it is necessary to understand how learning for, support and guidance within and across work life can be directed in ways to assist the development of capacities aligned with the digitalisation of work activities (Ley, 2020; Wallin et al., 2020).

A key consideration is that the impacts of this change may fall heaviest on workers with existing skilful knowledge and ways of knowing. These workers have been most impacted by new technologies, because of loss of competence and occupational subjectivity. Often these technologies are unique to specific kinds of work functions, operations, equipment and means of working and not always occupationally wide. Given these forms of knowledge are often abstracted, not able to be experienced directly through sensory processes of sound, sight or feel, they need to be represented in ways allow workers to engage with, mediate and construct knowledge of them. This kind of learning has been the focus of instructional efforts and interventions within educational institutions in the past. For instance, science education has sought to make conceptual knowledge accessible through converting it into symbolic forms. This then allows learners to 'read' that knowledge and generate symbolic representations such as those that underpin engagement in text and speech.

However, for the practicalities as well as pedagogic effectiveness, much of the mediation of this knowledge across working life now needs to occur within and through work and work practices. So, the challenges for lifelong or worklife learning here are at least threefold: i) the learning of conceptual and procedural knowledge that is difficult to access; ii) overcoming threats to workers' sense of self or subjectivity; and iii) much of this learning will need to occur within and through practice. This leads to the suggestion that the very technologically-mediated processes that have disrupted existing and traditional ways of working may also now need to play a key role in making the conceptual and procedural knowledge accessible (Nørgård, 2021). This can occur through symbolic means and in assisting workers' mediation of that knowledge continually so that they are able to develop further their understandings, procedures and selves as workers across working life.

Conflicts of interest and ethical clearance

There are no conflicts of interest in the review presented here, and ethical clearance resides within the published work that is drawn upon in this review.

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