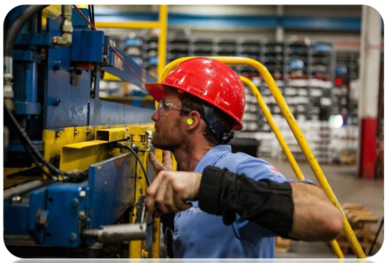
Manufacturing work by design

Pillars of successful integration of Industry 4.0 technology into jobs



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The Job Design Framework

The introduction of new technology can be a time of excitement and trepidation for a business and its workers. A business case may be developed to determine the value proposition, the benefits and return on investment. There may be significant cost and, depending on the size of the technology, changes to the layout of the factory or office will be considered or made. When businesses plan for technology adoption, they focus attention primarily on the 'kit' and what is required to put it in place. There is often less emphasis on the users of that technology. However, people (workers, staff) have a critical role to play in the success of any technology – particularly when it is new.

This document provides an overarching job design 'framework' and summary of significant changes to manufacturing work (current and anticipated) resulting from the introduction of emerging, disruptive Industry 4.0 enabling technologies. This focused report complements previous analysis applying a more macro lens (Worrall & Spoehr, 2021).

Technology alone will not shape the future of work; social context, dialogue and process are key

(Schulte et al., 2020, p.806)

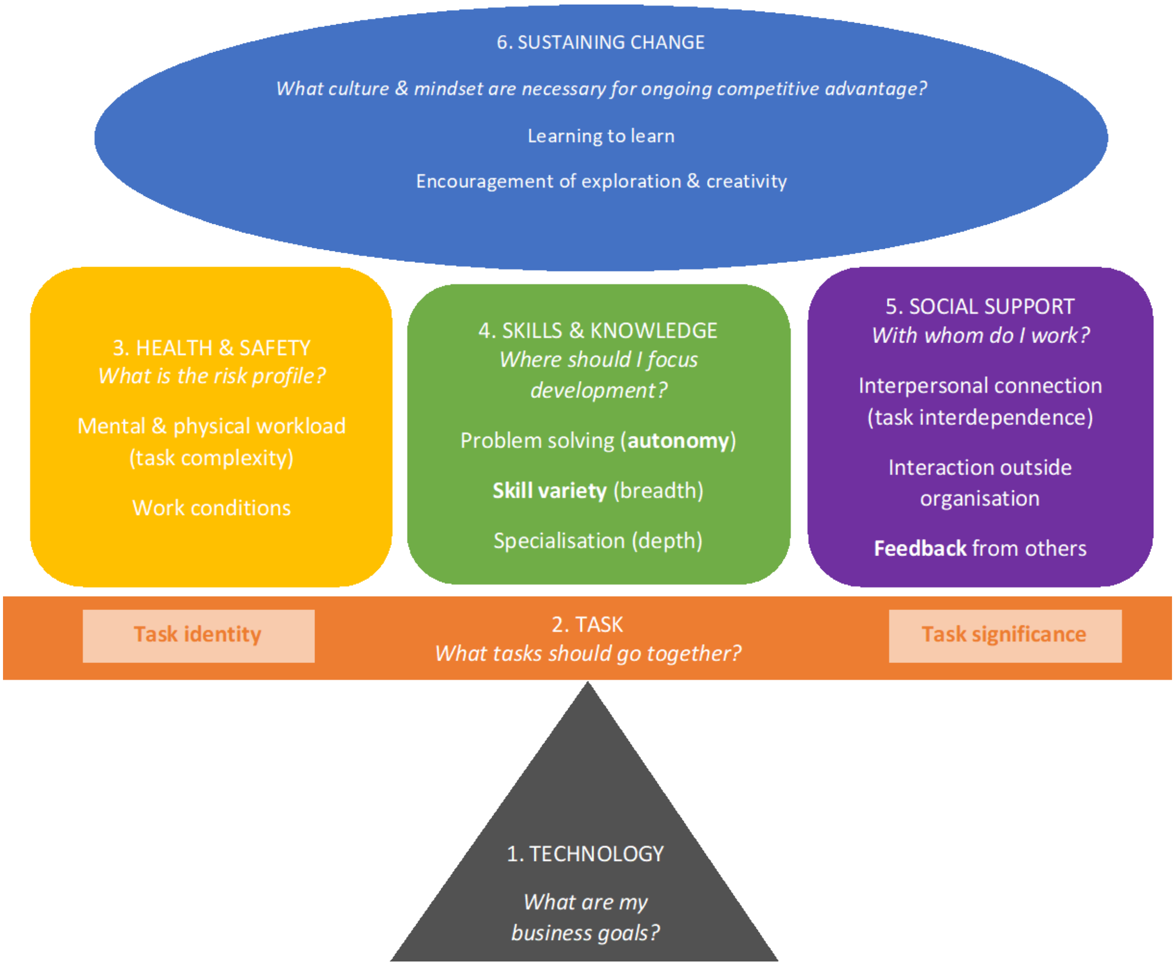
The framework draws on evidence-based psychological theories and models to guide and support the introduction and management of advanced technologies in the workplace with the aim of promoting awareness of good job design that will lead to a productive, safe and satisfied workforce. Good job design also minimises disengaged workers and supports retention thereby preventing additional pressures from workforce shortages. Moreover, changes to the role and responsibilities of traditional manufacturing jobs may enhance recruitment opportunities. For example, younger generations may have been averse to what they perceived as 'dull, dirty or dangerous' manufacturing jobs.

The framework provides a visual snapshot of technological and worker considerations when introducing business change. The sections that follow describe the six building blocks of the framework, defining concepts, providing examples and suggesting strategies to deliver them. The framework is grounded in human factors and ergonomics principles[1] such that the building blocks interact, are dependent on each other and change over time, working as a socio-technological system (i.e. made up of people working on tasks, using technology within an environment). As such:

- **Technology** is presented at the base as a fulcrum (or balancing point), emphasising its role to support task (job) accomplishment.
- **Task composition** is presented as a dynamic bar that shifts relative to the effort/load that is placed on it (i.e. job demands and resources – **health & safety**, **skills & knowledge** and **social support**).
- Broader **organisational culture and mindset** is needed to assist with reaching equilibrium across all the related components at any one time.

[1] Refer to *Quicker off the Blocks: The role of Human Factors in the uptake and diffusion of advanced technologies in shipbuilding* for more details, available at https://www.flinders.edu.au/australian-industrial-transformation-institute/human-factors-in-advanced-manufacturing

Figure 1: Job Design Framework



1. **Technology** – What are my business goals?

Despite manufacturers understanding the ‘why’ of Industry 4.0 adoption, information about the ‘what’ and ‘when’ of its implementation, particularly in the Australian context, is lacking.

> *Industry 4.0 has the potential to deal with fundamental and complex challenges, like globalisation or mass personalisation. However, the systematic implementation of Industry 4.0 technologies in production is complex due to a lack of expertise and research in the interactions between the single technologies.*
>
> (Dillenger, Bernhard, Kagerer, & Reinhart, 2022, p.11-12)

Industry 4.0 (also referred to as digitisation of manufacturing) is characterised by cyber-physical systems, automation, and data exchange (Butt, 2020). Associated technologies and systems can be applied across manufacturing processes (product design, manufacturing, commissioning, inspection and maintenance and decommissioning) and help address business (i.e. financial and reputational) and workforce (i.e. safety and wellbeing) needs resulting in competitive advantage.

More broadly, Industry 4.0 supports horizontal integration that allows companies to grow their market share (Mason, Ayre, & Burns, 2022). Table 1 summarises key Industry 4.0-related components (Geissbauer, Vedso, & Schrauf, 2016) and why they should be of interest.

Table 1: The scope for Industry 4.0 in your business

Technological component	What is it?	Potential business solution
Smart sensors[a]	Three components: a sensor that captures data (e.g. thermal, sound, location), a microprocessor that computes on the output of the sensor via programming, and communication capabilities (e.g. Bluetooth, Radio Frequency Identification (RFID)).	Enables more accurate and automated collection of environmental data; used for monitoring and control mechanisms. Supports effective decision-making.
Location detection/tracking	Technologies provide real-time information about the location of a device and thus its user[b] (e.g. Global Positioning System (GPS), WiFi (a wireless networking technology)).	Enhances user safety, especially in remote areas. Understand how and when tracked devices are being used (e.g. optimise routes, alert to unauthorised usage).
3D printing[c]	Otherwise known as additive manufacturing, is a process of making three dimensional solid objects from a digital file. An object is created by laying down successive layers of material until the object is created.	Allows you to produce complex shapes using less material than traditional manufacturing methods. Reduces dependence on supply chain, increases production flexibility.
Mobile devices	Small hand-held devices with a screen display and touch input (i.e. phone, tablet[d]).	Can reduce delays and bottlenecks by delivering the right (up-to-date) information at the right time to the right person.
Augmented reality/ wearables (e.g. headsets, glasses)	Enhances the physical, real-world environment by overlaying interactive digital contents (e.g. 3D images, text, sounds).	Reduces mental load when completing tasks as information is readily accessible. Wearables ensure hands are not occupied.
Industrial robots[e]	Automatically controlled, reprogrammable multipurpose manipulators, programmable in three or more axes, which can either be fixed or mobile. Collaborative robots or *cobots* are speed and force limited and considered ‘safe’ for humans to work in close proximity (i.e. are uncaged).	Generally designed to take on repetitive tasks and allow workers to focus on higher value duties. Collaborative robots allow for degrees of automation from coexistence with a person (shared space but not shared task) to full collaboration (shared space and shared task)[g].
Big data and analytics[h]	The use of advanced analytic techniques against complex (extensive and diverse) data sets for prediction and modelling. Algorithms are used to extract data.	Supports machine self-awareness and predictive maintenance and fault diagnosis. Facilitates improved planning and decision-making via data capture, curation and analysis with search, share, store, transfer and visualisation capabilities between machines and with people.

Technological component	What is it?	Potential business solution
Cloud computing[i]	Relates to the on-demand delivery of IT resources over the internet with pay-as-you-go pricing.	Instead of buying, owning, and maintaining physical data centres and servers, you can access technology services, such as computing power, storage, and databases, on an as-needed basis from a cloud provider.
Internet of Things (IoT) platform[j]	Bridges the gap between device sensors and data networks. It is a set of components that allows developers to spread out the applications, remotely collect data, secure connectivity, and execute sensor management.	Strives to connect devices remotely for seamless functioning and ease of operations. It provides insight into the data used in the backend application.

[a] https://www.techtarget.com/iotagenda/definition/smart-sensor [b] https://www.alrc.gov.au/publication/for-your-information-australian-privacy-law-and-practice-alrc-report-108/9-overview-impact-of-developing-technology-on-privacy/location-detection-technologies/
[c]https://3dprinting.com/what-is-3d-printing/
[d]https://csrc.nist.gov/glossary/term/mobile_device#:~:text=A%20mobile%20device%20is%20a,%2C%20tablets)%20throughout%20this%20document [e] https://ifr.org/industrial-robots [f] https://roboticsandautomationnews.com/2021/04/22/the-role-of-robotics-and-automation-in-industry-4-0/42638/ [g]Aaltonen and Salmi (2019); [h] Kang et al. (2016); [i] https://aws.amazon.com/what-is-cloud-computing/
[j] https://www.hcltech.com/technology-qa/what-are-iot-platforms

These technologies are often associated with the following benefits:

- Improved productivity and efficiency
- Reduced waste
- Reduced costs
- Higher revenue
- Increased flexibility of production
- Improved quality
- Easier compliance with regulations
- Increased transparency, knowledge sharing and collaborative working
- Improved health and safety
- Counter absence of skilled labour
- Improved authentication and fraud detection
- Enhanced customer experience (multilevel customer interaction and profiling)

(Cimini, Pezzotta, Pinto, & Cavalieri, 2019; Kiel, Muller, Arnold, & Voigt, 2017)

A more exhaustive summary of Industry 4.0 technologies is provided by German-based Dillenger et al. (2022) who also propose the following Industry 4.0 implementation sequence, validated by industry experts:

- **Level 1:** Security (e.g. cyber-security and data privacy) – providing a secure and legally compliant system
- **Level 2:** Computerisation (e.g. wireless networks and sensors)
- **Level 3:** Connectivity (e.g. cloud computing, big data, additive manufacturing)
- **Level 4:** Visibility (e.g. machine-to-machine communication, human machine interaction, horizontal and vertical system integration) – enables data-based decision-making
- **Level 5:** Transparency (e.g. augmented reality, collaborative robots, data analytics) – provides decision support and analyses complex cause and effect relationships
- **Level 6:** Predictive capacity (e.g. automated guided vehicles, digital twin, predictive analytics) – based on independent machine communication and autonomous control circuits
- **Level 7:** Adaptability (e.g. cyber-physical production system) – connects objects in the real world with virtual objects and acts autonomously.

In Australia, a recent study of 20 manufacturing companies showed that robotics, modernised software, sensors and additive manufacturing were primary in terms of Industry 4.0 adoption. In contrast to the implementation sequence recommended by Dillenger et al. (2022) data security was among the lowest considerations (Mason et al., 2022).

> *…lack of diversity, domestic focus and the dominance of small to medium enterprises will influence the way in which Australia experiences Industry 4.0.*
>
> (Mason et al., 2022, p.6)

APPROACH

You may already have a clear idea of where to seek improvements to your business and what technology you want to implement. Irrespective of this, gathering data to inform and support decisions will improve innovation success. Consider some of the following approaches to achieve this:

- Review financial statements, injury claims, incidents and absenteeism
    - Are there any longitudinal trends?
    - Is performance uniform across the business?
- Conduct a staff engagement survey or discussion forum regarding perceived current pain points
    - Encourage/incentivise suggestions for ways to improve these
- Investigate workforce interest and current capability in digital technologies; form a working group to leverage this motivation and knowledge (also see Section 6).

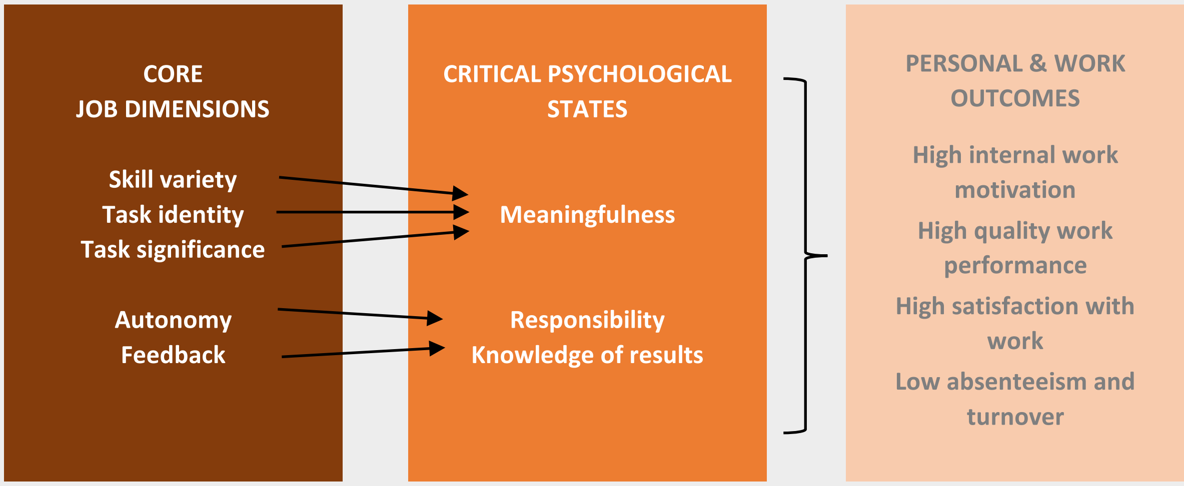
Be mindful that the introduction and adoption of any technology will change workflows and job composition which can have negative consequences for people if not adequately considered or managed well.

2. **Task** – What tasks should go together?

Every job is made up of different tasks. These can include a variety of skills that require the use of a person's body, brain and social capabilities (Gibbs, 2017).[2] In traditional manufacturing environments, tasks predominantly involve skilled *manual* labour (e.g. handling of heavy machinery and equipment).[3] The introduction of Industry 4.0 technologies has disrupted the roles of many production and operation staff who now undertake tasks with higher level oversight requiring skills such as process coordination, evaluation of machine performance and monitoring quality control.[4] More broadly, these tasks relate to the concept of integrated manufacturing which draws on advanced manufacturing technologies, total quality management and just-in-time inventory management principles (Bayo-Moriones, Bello-Pintado, & Merino-Diaz-de-Cerio, 2010).

Whether work involves traditional or more innovative tasks, their fundamental qualities influence our motivation to do a job and the quality of performance delivered (Hampel & Sassenberg, 2021). This relationship between motivation and performance quality is captured by the Job Characteristics Model which suggests that for employees to remain engaged and productive, jobs need to provide skill variety, task identity, task significance, autonomy and feedback (see Figure 2).[5] Task identity and task significance will be discussed below with the other dimensions discussed in later sections of the report.

Figure 2: The Job Characteristics Model



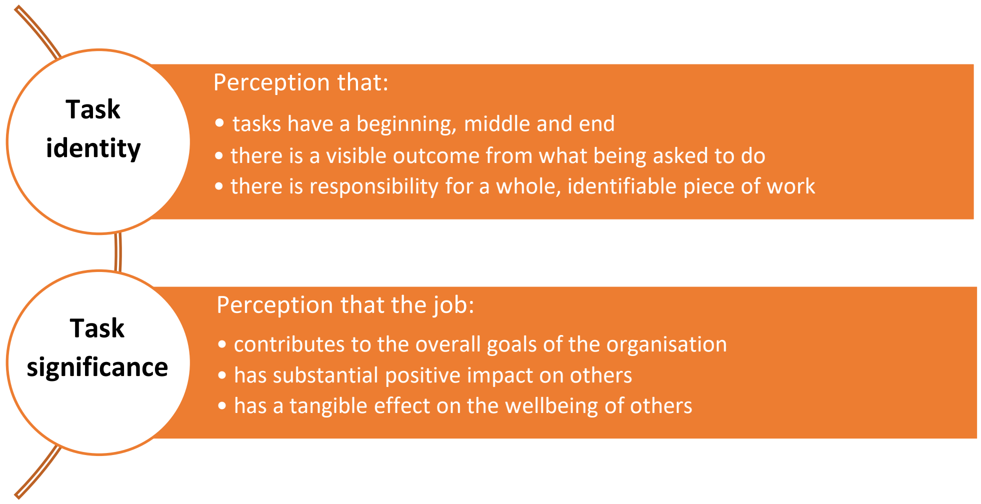
Modified from Hackman and Oldham (1975)

When employees contribute to an entire task from start to finish (rather than just a portion or subset of the task) and see the outcome of their efforts (also see Figure 3) they experience task identity. For example, a carpenter who transforms pieces of wood into a chair would have greater task identity (and thereby sense of meaningfulness) than an assembly worker completing one or two

[2] See Section 4 for more discussion on Skills & Knowledge.
[3] https://www.tafecourses.com.au/resources/blue-collar-vs-white-collar/
[4] https://www.bcg.com/publications/2015/technology-business-transformation-engineered-products-infrastructure-man-machine-industry-4
[5] https://www.aihr.com/blog/job-characteristics-model/

components of a television or car. Experienced meaningfulness is one of the strongest facilitators between all core job characteristics and work outcomes (Johns, 2010).

Figure 3: Descriptions of task identity and significance related to the Job Characteristics Model



Derived from the Job Characteristics Model, Hackman and Oldham (1975)

The change in work tasks as a result of Industry 4.0 has the potential to support high task identity given the reduced focus on 'doing' the work and increased need to oversee, coordinate and understand all components of the technology and task. However, a role that only requires overseeing a collaborative robot that assembles one or two components of an electrical switchboard, for example, is unlikely to achieve high task identity. Thus, introducing technology alone will not address poor workflows or alleviate poor job design (i.e. the way a set of tasks is organised).

> The process of adding extra tasks to a job is referred to as **job enlargement**

Task identity can be improved through various methods,[6,7, 8] including but not limited to:

- Grouping interrelated tasks together. Involving employees in more aspects of the work such as planning, reporting and evaluation of the effectiveness of methods used
  - Regular participation in Quality Circles/Kaizen groups or similar can help provide an understanding of cause and effect
- Communicating to employees how the job/tasks they complete contribute to the final product
  - Ensure there are a range of documents or communication tools that capture the bigger picture (e.g. organisational charts, dependency workshops involving multiple teams)
- Allowing employees to finish work they start rather than it being handed off to other employees part-way through the process.

[6] https://www.forbes.com/sites/datafreaks/2014/09/25/motivating-employees-has-almost-nothing-to-do-with-their-attitude-and-almost-everything-to-do-with-feelings-of-ownership/?sh=607b69551140
[7] https://www.aihr.com/blog/job-enrichment/
[8] https://www.saviom.com/blog/project-interdependencies-span-portfolio/

Task significance has been described as the extent to which a job has *'a substantial impact on the lives or work of other people—whether in the immediate organisation or in the external environment'* (Hackman & Oldham, 1975, p.161). Those in jobs with broader reach and who make decisions that are likely to influence or impact the whole business (often management level roles with higher organisational oversight) tend to experience greater task significance.[9,10]

> *When employees experience their jobs as high in task significance, their actions have a frequent, lasting impact on the lives of others*
>
> (Grant, 2008, p.110)

APPROACH

Task significance can be enhanced by increasing a sense of connectedness, for example by:

- Encouraging employees to help each other
    - Create ways to reflect on and capture how help and support is provided across the business and the flow-on effects from this
- Creating equal opportunities for employees to meet clients, customers and product end users (i.e. those who are likely to benefit from an employee's work)
    - Regularly share stories of positive impact throughout the business

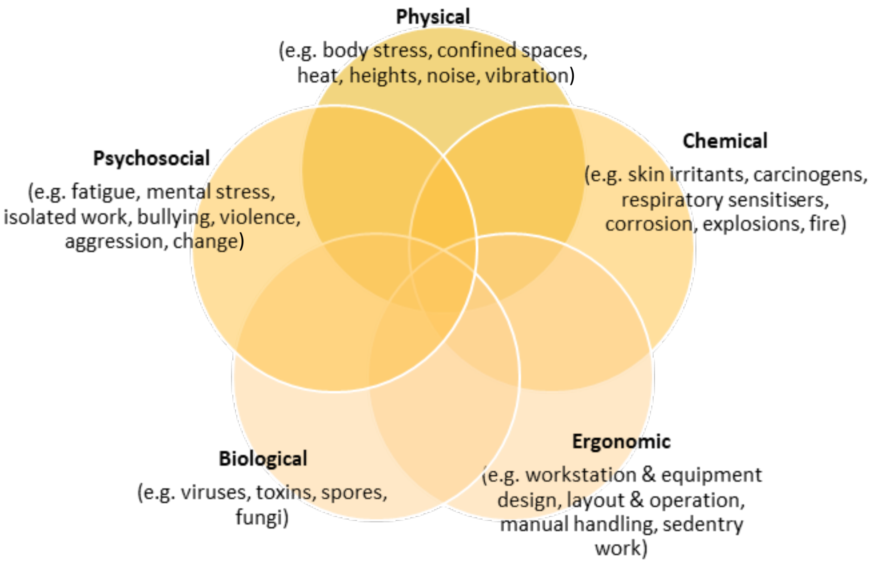
[9] https://www.aihr.com/blog/job-characteristics-model/

[10] Section 5 also discusses the importance of relationships at work.

3. **Health & Safety** – What is the risk profile?

Every workplace has hazards that need to be controlled and mitigated. The Australian Government (2021)[11] has identified five general categories of workplace hazards (see Figure 4) for employers to be alert to, monitor for, and prevent wherever practicable. Alternately, an 'A to Z' list of 35 specific hazards has been compiled by Safe Work Australia;[12] while Safe Work NSW's extended list includes a technology specific hazard – mobile communication devices (e.g. two-way radios, phones, tablets) – which can cause distraction and reduce situation awareness and reaction times.[13]

Figure 4: Summary of workplace hazards



Traditionally, manufacturing work has been associated with a high number of injuries, illnesses and death. Common hazards in manufacturing which primarily result in physical injury include:[14]

- Manual handling (i.e. lifting, pushing and pulling)
- Slips, trips and falls
- Working with dangerous machinery and equipment
- Hazardous chemicals
- Noise.

In general, musculoskeletal disorders remain the leading work, health and safety problem for Australian employers and employees, both in terms of frequency and cost (Oakman, Clune, & Stuckey, 2019). In manufacturing and construction, musculoskeletal disorders often arise from a combination of:

- Repetitive actions in handling tools and parts (even lighter weights) during production
- Fast-paced work
- Working in awkward postures, with or without high force application
- Handling heavier loads above 15 kilograms
- Tasks of long duration, leading to fatigue.

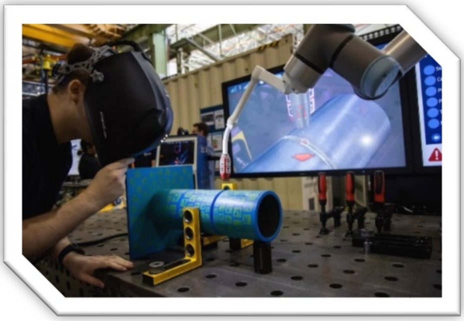
[11] https://www.comcare.gov.au/safe-healthy-work/prevent-harm/psychosocial-hazards
[12] https://www.safeworkaustralia.gov.au/safety-topic/hazards
[13] https://www.safework.nsw.gov.au/hazards-a-z/mobile
[14] https://www.safeworkaustralia.gov.au/safety-topic/industry-and-business/manufacturing

Moreover, the risk profile of these activities can be exacerbated if work is undertaken in harsh environments such as those involving large-scale sites (e.g. shipyards), temperature extremes, confined spaces, poor air quality (i.e. from dust, fumes and chemicals), and risk of exposure to physical hazards (e.g. electricity, ingress of substances and mechanical hazards), or when working under pressure (too much work, insufficient time to complete work) when errors become more likely and can lead to re-work. High mental demands are also a risk factor associated with incidence of musculoskeletal disorders (Fadaei, Habibi, & Hasanzadeh, 2020).

Industry 4.0 technologies provide opportunities to ameliorate some of these workplace conditions and hazards. However, changes to workflow and the redesign of work processes and practices due to the insertion of technology can create a new risk profile rather than simply diminishing the existing one. Examples of Industry 4.0 technology are discussed below.

Collaborative robots

Collaborative robots[15] (cobots) are speed and force limited industrial robotic arms designed with reduced pinch-points, smooth joint-shells and in-built safety sensors. Such sensors cause the cobot to stop (i.e. avoid contact with a person) when they detect impact or abnormal forces. This means people can work near them without the need for protective cages.



Cobots can perform highly repetitive work for long durations with accuracy and efficiency, freeing people to focus on higher value tasks such as coordinating and controlling work processes using decentralised decision-making (Leso, Fontana, & Iavicoli, 2018). However, as management-type activities increase, workload is likely to intensify (Schulte et al., 2020).

Exoskeletons (wearable robotic technology)

An exoskeleton refers to an external frame (active/powered or passive/energy-storing and hard or soft frame) that can be worn to support and enhance a workers' physical capabilities by minimising loading on the body (e.g. shoulder, arm and hand; lower back; leg, hip, knee and ankle) during physically demanding tasks. The frame can provide additional movement, strength and endurance, including the ability to handle heavier loads in awkward postures.

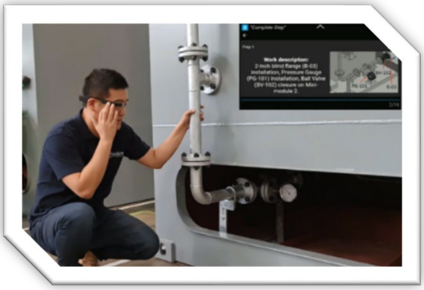
Using the exoskeleton may inadvertently give workers a false sense of security and embolden them to work in environments or on tasks that continue to pose dangers - or work longer hours (impacting on work-life balance). In addition, wearing an exoskeleton can be associated with increased chest pressure and reduced natural movement, whereas ill-fitting exoskeletons may also lead to discomfort and increased shear or pressure injuries.[16,17] In addition, use of exoskeletons in manual handling activities may increase mental workload, at least initially, due to additional processing

[15] For more more information see *Robots and the Digital Shipyard* and *From Ship to Shore: Reducing the barriers to collaborative robot uptake in shipbuilding and manufacturing through human factors*, https://www.flinders.edu.au/australian-industrial-transformation-institute/human-factors-in-advanced-manufacturing
[16] https://amtrustfinancial.com/blog/loss-control/exoskeleton-and-exosuits-in-the-workplace
[17] https://www.ehstoday.com/safety-technology/article/21138659/exoskeletons-the-good-the-bad-and-the-ugly

requirements associated with supporting motor control and planning (Zhu, Weston, Mehta, & Marras, 2021).

Quadruped robots, drones

Some technology can reduce or even eliminate the need for workers to be exposed to harsh or isolated environments by enabling work to be completed remotely or autonomously. Mobile robots, like quadruped robots (e.g. Boston Dynamic's Spot - pictured) and drones, when equipped with appropriate payloads (e.g. cameras, lights, sensors and lasers), allow for site and installation inspections, detection of hazardous atmospheres and capture digital records.



The end result may be that work becomes less dirty and dangerous but more sedentary (i.e. reduced physical activity due to increased monitoring of screens), contributing to a risk of long-term chronic health conditions like obesity and heart disease.

Augmented reality

Augmented reality[18] (i.e. Google glasses and Hololens 2 - pictured) can be used to provide additional information when and where needed, reducing reliance on (and the need to search for) paperwork and face-to-face expertise. This may reduce frustration caused by information-related bottlenecks and can also increase the pace of work, reduce physical activity and hamper relationship building.[19]

Wireless communication, sensors and big data

Large-scale monitoring of the work environment, traffic management, machine performance and individual worker behaviours is supported (on a wide range of devices) by wireless communication, sensors and big data enabling predictive analytics for greater reliability and safety outcomes (Badri, Boudreau-Trudel, & Souissi, 2018). However, unintended consequences of such technologies may include surveillance and intrusion of workers' privacy, increasing stress and straining working relationships. In addition, having access to digital technologies that provide a constant accessible information stream can promote an 'always on' culture, increasing stress (Robertson & Cooper, 2018).

[18] For implementation guides on Spot and Hololens 2, see https://www.flinders.edu.au/australian-industrial-transformation-institute/human-factors-in-advanced-manufacturing

[19] Also see Section 5

APPROACH

Ideally, tasks that comprise a job should involve a balance of physical, mental and relational components to minimise risks and promote benefits. In addition to conducting risk assessments of new technologies and tasks and upholding mandatory work health and safety policies and procedures, some approaches (below) may enhance health and safety in your workplace:

- Monitor workload perceptions to avoid people feeling under- (leading to boredom and disengagement) or over-loaded (leading to stress and burnout)
    - The NASA Task Load Index is a short, six-item self-report questionnaire that explores: mental demand, physical demand, temporal demand/pace, performance, effort and frustration. This can assist in understanding which aspects of a task are potentially problematic
- When the balance of task types or risk profiles change, consider providing other opportunities and forms of support to counter any impact, where possible. For example:
    - Provide an onsite gym if physical demands are reduced
    - Change layout or workflow to encourage movement throughout the day
    - Increase the frequency of breaks
- Pilot technology with a range of workers (e.g. age, experience, physical stature) prior to broader rollout
    - This will assist with early identification of points of frustration, hazards or unintended consequences and allow employers to proactively address these.

4. **Skills & Knowledge** – Where should I focus development?

Technology is changing the nature of all jobs, eliminating many repetitive tasks and optimising others. Research has shown that both cognitive and social tasks are difficult to automate (Gibbs, 2017) so these skills are likely to have ongoing relevance in the future of work (Frey & Osborne, 2017). Unique skills for humans include communication, ethical judgement, teaming, collaboration, creativity and the ability to motivate others (Bhargava, Bester, & Bolton, 2021). Thus, some experts emphasise the importance of non-technical skill development (Rotatori, Lee, & Sleeva, 2021). In contrast, others investigating human resource management trends in personnel selection in the Industry 4.0 era emphasise selection of candidates with strong technical skills and entrepreneurship (Ada, Ilic, & Sagnak, 2021)(see Table 2).

Table 2: Important skill sets and their competencies for recruitment and selection of personnel in an Industry 4.0 landscape

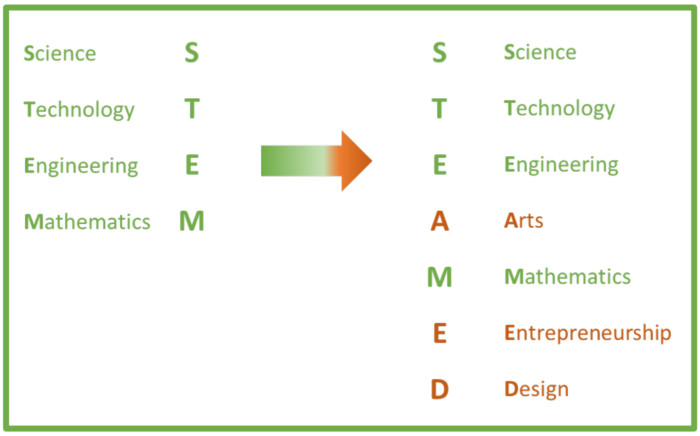
Workforce Readiness	Soft Skills	Technical Skills	Entrepreneurship
Literacy	Communication	Computer Programming	Initiative
Numeracy	Critical Thinking	Coding	Innovation
Digital Literacy	Creative Thinking	Project Management	Creativity
Resume Writing	Collaboration	Financial Management	Industriousness
Self-Presentation	Adaptability	Mechanical Functions	Resourcefulness
Time Management	Leadership	Scientific Tasks	Resilience*
Professionalism	Social-Emotional Learning	Technology-based Skills	Ingenuity
Etiquette	Teamwork		Curiosity*
Social Norms	Self-Confidence		Optimism
	Empathy		Risk-Taking*
	Growth Mindset*		Courage
	Cultural Awareness		Business Acumen
			Business Execution

Based on table in: Ada et al. (2021, p.778). Shaded cells reflect competencies considered more influential.
**Reflect competencies that are important to learning and problem-solving (see Section 6).*

Many jobs (listed below) related to Industry 4.0 and associated technologies place high demands on IT skills (MECB, 2020):

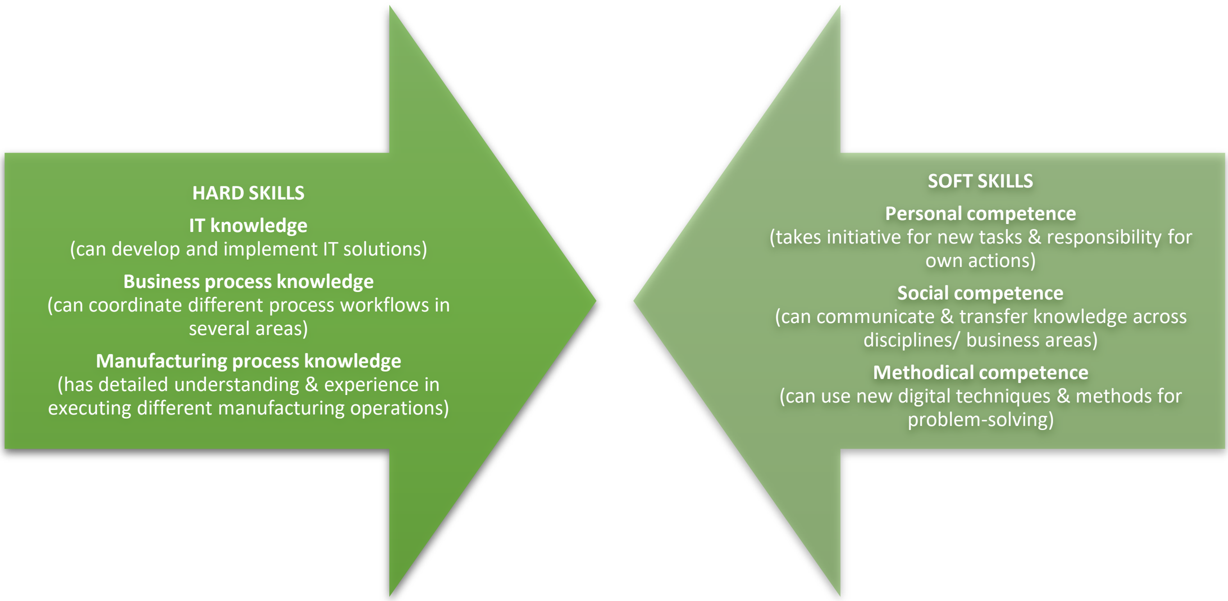
- Business Intelligence Specialist (Data Science and Consulting)
- Automation Engineer
- Software Engineer for Robotic Systems
- Cloud Architect and Software Developer (Java/Cloud/Android)
- Factory manager
- Chief digital officer
- Cyber security engineer/advisor
- Machine maintenance
- Control of industrial machines, logistics, packaging
- Software developer
- IT advisory consultant
- Simulation expert
- Digital forensic investigator

For businesses to benefit from Industry 4.0, employees need a combination of both technical and non-technical skills to work effectively and remain competitive (Seet, Jones, Spoehr, & Hordacre, 2018). This thinking extends the acronym STEM to STEAMED (Hordacre, Spoehr, & Barnett, 2017), as shown below.



Galaske, Arndt, Friedrich, Bettenhausen, and Anderl (2018)'s 'Toolbox Workforce Management 4.0' represents this challenge as requiring the development of both hard (acquired through formal education and/or work experience) and soft skills (represent competencies and qualifications associated with an employee's personal characteristics and observed in interpersonal relationships) - both of which can be learned, although 'soft' should not to be mistaken for 'easy' to develop (see Figure 5).

Figure 5: Meeting in the middle – Knowledge requirements for Workforce 4.0



Source: Based on Galaske et al. (2018)'s framework

Individuals who possess a mix of hard and soft skills are labelled as 'T-shaped' and make valuable employees. The vertical part of the 'T' represents depth of their knowledge, technical skills or specialisation (e.g. proficiency in programming) and the horizontal part of the 'T' represents other broader skills (e.g. communication, creativity, emotional intelligence) which assist collaboration and application of expertise to other domains (Bodell, 2020). Bodell (2020) describes them as a hybrid between generalists and specialists.

> *Industry 4.0 adoption allows novel forms of human-machine interactions. Operator 4.0 can interact with Industry 4.0 technologies, physically and cognitively. Such interplay delivers qualitative benefits to Operator 4.0 in terms of a more enjoyable working environment, greater autonomy, and self-development*
>
> (Margherita & Bua, 2021, p.19)

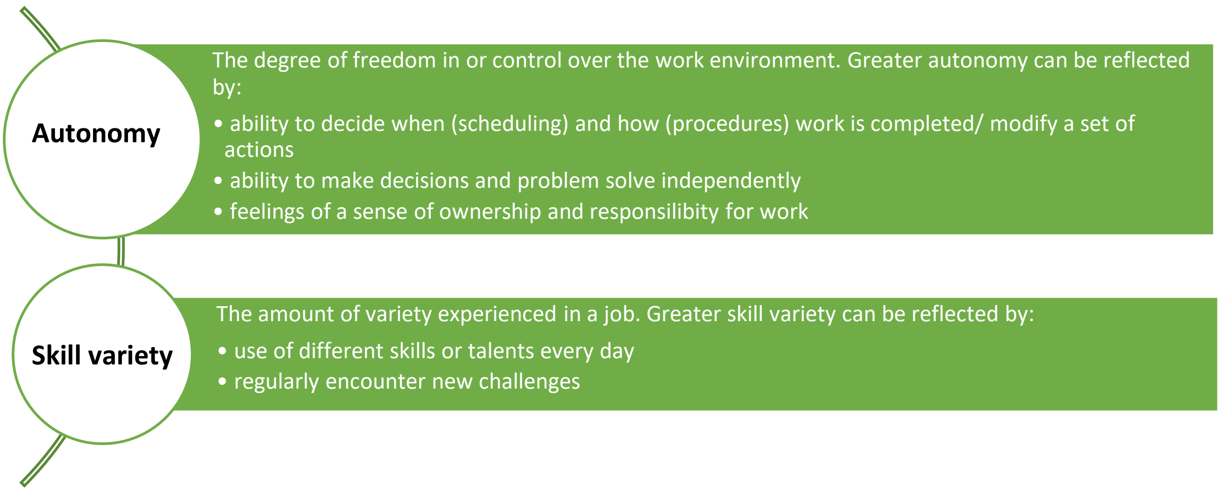
Once such talent is developed or procured, it is important an individual's job is structured so they can use the breadth and depth of their skills (see Figure 6 for more details). The introduction of Industry 4.0 technologies can promote the diversification of manufacturing through designing and producing customised products and services, leading to new roles, skills and responsibilities, and as such it can increase variety in a job. Rapid skill acquisition is integral to technology adoption involving automation and smart technologies and extends conventional manufacturing skills. Work will be transformed from a reliance on psychomotor skills to cognitive skills requiring the application of theoretical and abstract knowledge (Schulte et al., 2020) and sharing tasks to complete more complex operations quickly (Badri et al., 2018).

However, employee autonomy (see Figure 6) may not be enhanced with the introduction of Industry 4.0. Cirillo, Rinaldini, Staccioli, and Virgillito (2021, p.167) observed that,

> *While operators previously used to enjoy the possibility of autonomously defining the manner and order of execution of a given procedure entailing the use of manual tools, nowadays the widespread adoption of digital tools typically requires tasks to be performed according to a unique admissible combination of steps, otherwise errors are raised.*

Employers will need to be particularly mindful that autonomy is not diminished with changes to jobs. *'One of the unintended consequences that a reduction in autonomy often has is a diminution in learning or the motivation to execute learning'* (Johns, 2010, p.362) which could jeopardise necessary Industry 4.0 skill development and utilisation.

Figure 6: Descriptions of autonomy and skill variety



Derived from the Job Characteristics Model, Hackman and Oldham (1975)

Workplaces can improve employee outcomes through[20]:

- **job enrichment** where employees are given the opportunity to take on some tasks typically done by managers (e.g. planning, executing and evaluating work)
- **job rotation** where employees are temporarily exposed to different areas of the business. This tends to involve lateral movement and is not a promotion

Specifically, Butollo, Jurgens, and Krzywdzinski (2018, p.13) propose:

> *Increasing individual autonomy in a highly interdependent and standardised work process might not be a feasible strategy for improving work quality. A more promising approach might focus on enriching work in the sense of including more problem-solving and optimisation activities (which also provide learning opportunities) and providing more time autonomy i.e., more freedoms to switch between production work and other activities*.

The need to build green skills at all levels of the workforce is increasingly prominent in order to develop sustainable business. Green skills *'are those skills needed to adapt products, services and processes to climate change and the related environmental requirements and regulations'* (OECD, 2014, p.2). These skills encompass knowledge, abilities, values and attitudes that *'develop and support sustainable social, economic and environmental outcomes in business, industry and the community'* (NCVER, 2013[21]). Specifically, these skills relate to[22]:

- Pollution prevention (e.g. sustainable design, fashion, business strategies)
- Ecosystem management (e.g. environmental awareness, environmental services, climate, surface water, sustainable landscapes)
- Environmental remediation (e.g. recycling, oil spill response)
- Environmental auditing (e.g. environmental management systems, environment, health and safety, sustainable growth)
- Environment policy (e.g. ISO 14001, occupational safety and health, corporate social responsibility)
- Renewable energy generation (e.g. solar systems)

Overall, due to the drastic and fast-paced nature of change associated with Industry 4.0 technology, a willingness and ability to unlearn, learn and relearn is crucial for longevity of the future workforce (Ra, Shrestha, Khatiwada, Yoon, & Kwon, 2019).[23] In addition, building psychological capability to deal with 'VUCA' environments – those involving volatility, uncertainty, complexity and ambiguity[24] – will be paramount. Supporting workers to cope with uncertainty is important (Cropley & Cropley, 2021). Bradberry (2015) [25] provides some 'emotional intelligence' strategies to promote and manage uncertainty. Education and vocational training[26] providers will need to work hard to keep up with training demands (Ra et al., 2019), as will the business community who provide essential on-the-job training.

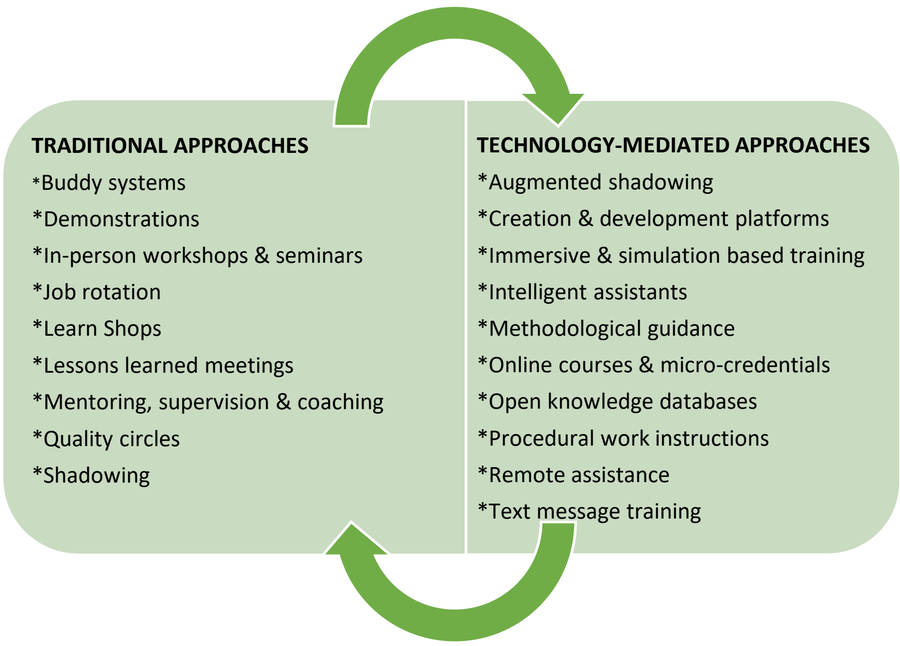
[20] See Section 5 for more discussion on task interdependence.
[21] https://www.voced.edu.au/content/glossary-term-green-skills
[22] LinkedIn Economic Graph (2022). Global Green Skills Report 2022. https://economicgraph.linkedin.com/content/dam/me/economicgraph/en-us/global-green-skills-report/global-green-skills-report-pdf/li-green-economy-report-2022-annex.pdf
[23] Also see Section 6.
[24] https://hbr.org/2014/01/what-vuca-really-means-for-you
[25] https://www.forbes.com/sites/travisbradberry/2015/12/21/11-ways-successful-people-overcome-uncertainty/?sh=55935edf2475
[26] Evidence suggests that this is particularly the case for vocational education and training providers; see Seet et al., 2018.

It is important to recognise that Industry 4.0 technologies can serve as both the push (reason for upskilling) and pull (facilitate the upskilling) in learning and development, akin to the concept of Education 4.0 (e.g. Mourtzis, Vlachou, Dimitrakopoulos, and Zogopoulos (2018)). Roth and Moencks (2021) provide a summary of the complementary traditional and Industry 4.0 - enabled learning tools utilised in industry (see Figure 7). However, as with most solutions, one size does not fit all, and the most appropriate learning approach (or combination thereof) will need to be tailored to the specific work context (Lieb, 1991).

Education which combines technological skills and required mindsets is referred to as 'dual-track.'

(Cropley & Cropley, 2021)

Figure 7: Examples of different learning solutions among industry



Derived from Roth and Moencks (2021)

Technology-mediated learning has many advantages, including it is personalised, scalable, includes formal and informal learning and real-time feedback (Roth & Moencks, 2021).[27] Roth and Moencks's framework describes the range of teaching media that can be applied (learning solutions), shares a practitioner guideline on how to implement the learning solutions, and provides an evaluation guideline to evaluate success.

Stavropoulos, Korfiati, Panopoulos, and Mourtzis (2021) propose a four-tier model of technology-enhanced 'Smart Learning', an approach that improves knowledge, skills and competencies through:

- Online learning (or e-learning, supports synchronous (real time) and asynchronous learning)
- Blended or hybrid learning (combines face-to-face and virtual teaching)
- PC based simulation tools (essential to adequately prepare employees for real-world situations)
- Digital learning games (serious, interactive games provide exciting learning experience).

[27] Also see Section 5.

Teaching factories are viewed as a contemporary mechanism to educate and attract talent to manufacturing and promote implementation of cyber-physical-systems[28] in industry (Mourtzis et al., 2018). Teaching factories provide students/employees with realistic, active, practical experience in the phases of product design and production while familiarising them with modern manufacturing techniques (e.g. advanced visualisation techniques, augmented reality, sensor data integration and analysis) (Mourtzis et al., 2018).

A teaching factory is a collaboration space where practitioners bring experience from the factory to teach students, while students and faculty bring knowledge from the classroom to teach practitioners. The collaboration is supported with a web conferencing platform and is an ongoing process, with regular sessions and continuous interaction between the factory and the classroom

https://www.eitmanufacturing.eu/what-we-do/education/resources/teaching-factory/

Aligned with the principles of adult learning[29], Rangraz and Pareto (2021) suggest adhering to the following features for success when engaging in workplace-based training (work integrated learning):

- Ensure content is relevant – contextualise and tailor content/merges theoretical and practical content
- Provide incentive to learn – content and approach inspires interest in technology adoption (e.g. attendance at technology fairs; involve interaction between key workplace personnel)
- Utilise existing competencies and skills - use domain knowledge and experience as foundations for learning
- Allow work processes to be prototyped – use simulations so early learning is safe and well-paced
- Adopt an apprenticeship (or train-the-trainer) model – the first group of learners become the first group of teachers
- Knowledge systems should draw on multiple sources so content can be integrated and readily accessed to support ongoing learning.

[28] This is where sensors are embedded in production equipment to monitor processes. The sensors are connected by a wireless network that collects, records and stores data in a database (Mourtzis et al., 2018).
[29] https://ala.asn.au/adult-learning/the-principles-of-adult-learning/

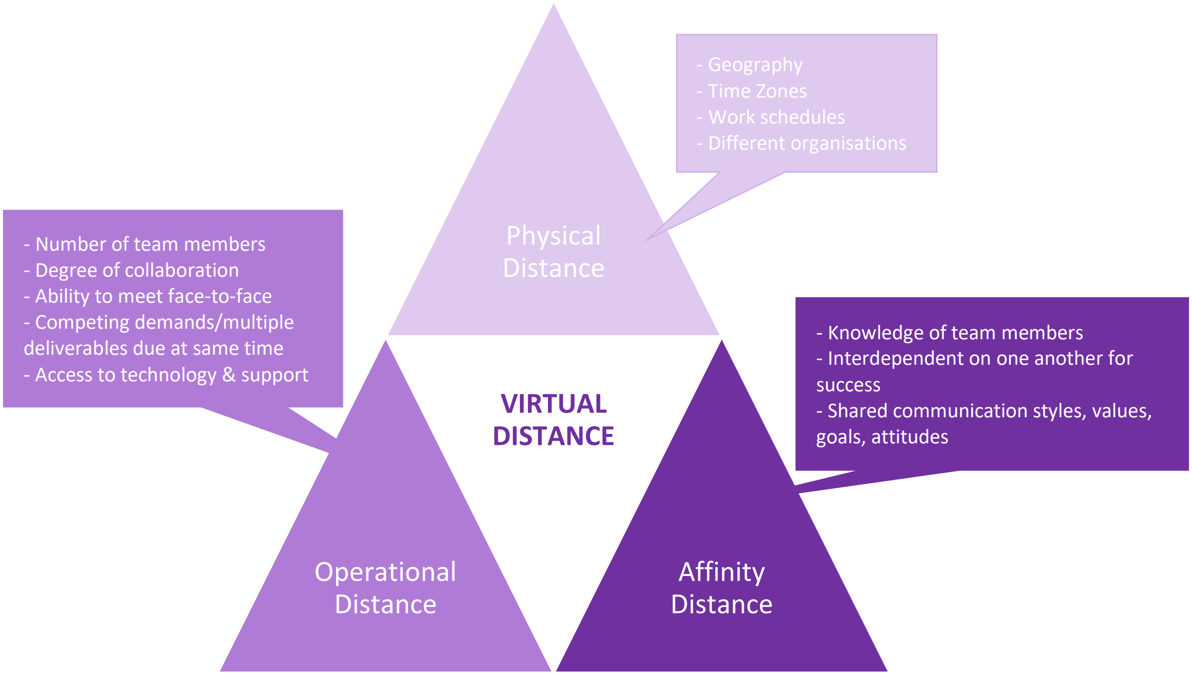
5. **Social support** – With whom do I work?

The introduction and diffusion of Industry 4.0 technologies has the potential to decrease face-to-face communication, grow remote work and increase the opportunity for employees to communicate, collaborate and coordinate with a broader range of colleagues and stakeholders (Flores et al., 2020). This shift may increase the virtual distance experienced by employees. Virtual distance is a sense of psychological and emotional detachment that begins to grow unconsciously when most engagement occurs with the use of screens or technology (Sobel-Lojeski, 2015). Virtual distance comprises three factors (see Figure 8) and if left uncontrolled, high virtual distance can have the following adverse effects on business (Sobel-Lojeski, 2015):

> Future workforce will need to be highly adaptable, resourceful, resilient and interdisciplinary for interaction and collaboration in the industrial market
>
> (Flores, Xu, & Lu, 2020, p.698)

- Innovative behaviours - fall by more than 90%
- Trust - declines by more than 80%
- Cooperative and helping behaviours – decrease by more than 80%
- Role and goal clarity - decline by 75%
- Project success - drops by more than 50%
- Organisational commitment and satisfaction - decline by more than 50%

Figure 8: Summary of the Virtual Distance Model



Source: Sobel-Lojeski and Reilly (2007)

To reduce virtual distance, improving (i.e. lowering) affinity distance (by bolstering relationship quality) will have the greatest long-term effect, but it is also perceived as the most challenging to accomplish (Ferrazi, 2012). Challenges arise because screens/technology often reduce information (i.e. tone, body language) which can lead to misinterpretations; distort the pace of conversations (if we don't receive an immediate response we can become distracted, second-guess ourselves or become frustrated with others); reduce informal/incidental conversations (which are essential to getting to know each other); and, at times, reduce visibility of what others are working on (which can create mistrust). To counteract these risks it is important to:

> The greater the Virtual Distance among the members of a team, the more problems team members will experience. Among them: miscommunication, lack of clearly defined roles, and even personal and cultural conflicts. It does not matter whether team members are widely distributed or collocated; every team is potentially subject to the risks of Virtual Distance.
>
> (Sobel-Lojeski & Reilly, 2007, p.5)

- Establish preferred communication methods among a team
- Match the urgency of the message with the medium (e.g. pick up the phone or have a face-to-face discussion if urgent/important). Do not use a single technology/format for all communication
- Allow time for socialising when conducting meetings or other events virtually
- Invite feedback and share achievements.

Structuring tasks and teams so they are interdependent will also help address high affinity distance. Task interdependence can be described as '*a measure of dependence on others' expertise*' (Lee, Park, & Lee, 2021, p.581)[30]. When tasks are interdependent, they are linked through their scope of work (e.g. end of a task prompts commencement of another), resources (e.g. the giving or receiving of materials, tools, information) or criticality (e.g. task influences upstream tasks) (Kiggundu, 1983; Lee et al., 2021) and require greater levels of connection. High task interdependence can be[31] associated with better performance outcomes (e.g. quality), reduced conflict, increased cooperation and information sharing, enhanced learning, adoption of more effective methods to complete tasks and greater trust (Langfred, 2007; Parker et al., 2001; Staples & Webster, 2008; Wageman, 1995).

Feedback is one element of social support (see Table 3) which in turn comprises part of the relational component of work.[32] Feedback is necessary in order to improve performance and understand how our work fits in to the bigger picture (i.e. promoting task identity and significance)[33] and, as discussed above, can help mitigate high affinity distance.

Feedback can take many shapes and forms but to be effective it needs to be timely, accurate and constructive. Prior to Industry 4.0, those on the production line may have needed to wait until a quality inspector reviewed

> Performance management is indeed changing tremendously. Whereas in the past, the generation of KPI dashboards was a major task and KPIs were only available at aggregated levels, now granular data is available in real time from internal and external sources. This moves the performance management process from a regular, often monthly process to an operational process aimed at exception handling and continuous improvement
>
> (Alicke, Rachor, & Seyfort, 2016, p.8)

[30] There are many definitions and nuances around task interdependence; refer to Courtright, Thurgood, Stewart, and Pierotti (2015) and Wageman (1995) for a review.
[31] There are interaction effects with other job design characteristics and context that may influence the extent of the relationships – see Parker, Wall, and Cordery (2001) and Staples and Webster (2008) for more details.
[32] https://www.smartworkdesign.com.au/relational
[33] Also see Section 2.

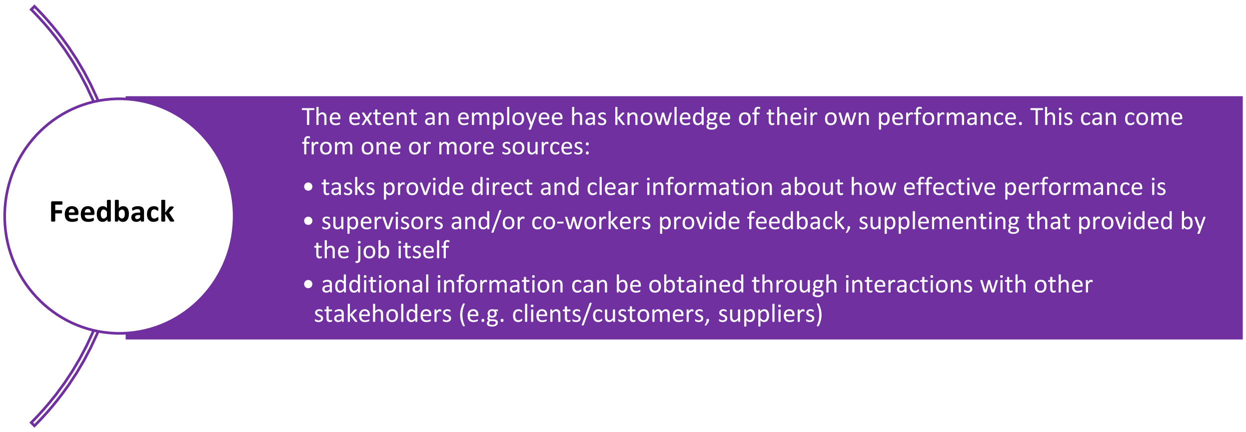
their work to know how effective they had been.[34] Today, Industry 4.0 is likely to increase the speed and amount of direct task feedback (creating ‘big data’), albeit through machine/technology interfaces. It will be important to manage the volume and visualisation[35] of feedback provided to prevent overloading employees[36] as well as ensure feedback is provided from other sources, preferably delivered face-to-face (see Figure 9).

Table 3: Types of social relationships in the workplace

Type	Description	Example
Emotional	Expressions of empathy, caring, appreciation	Colleagues listening to a problem and providing encouragement and compassion
Instrumental	Practical assistance and service	Colleagues helping to complete a task
Informational	Advice, suggestions, and information	Colleagues sharing relevant information and experience
Appraisal	Information that is useful for self-evaluation; feedback	Colleagues providing constructive feedback on performance

Source: https://www.med.upenn.edu/hbhe4/part3-ch9-key-constructs-social-support.shtml

Figure 9: Descriptions of feedback relating to the Job Characteristics Model



Source: Hackman and Oldham (1975)

[34] https://www.aihr.com/blog/job-characteristics-model/
[35] Nielsen (2020) identified ten key principles for enhanced interface design and user experience.
[36] Also see Section 3

Some useful feedback mechanisms include:[37,38]

- Hold regular check-ins and on-the-spot conversations
    - 'Shift huddles' (held standing up) – before, mid or at change of shift; 5-10 minutes in duration to exchange information, recognise performance and identify/problem-solve any actual or anticipated pain points (keeping fast and relevant is key)
    - Monthly individual conversations between supervisors and direct reports
    - Broader team meetings (fortnightly to quarterly depending on context)
    - Annual performance and development reviews
- Provide and visually track line-shift goals
    - Distinguish clear and concise goals for each line-shift or individual. Some common manufacturing metrics include:
        - Production quality
        - Waste/scrap analysis
        - Performance to schedule
        - Progress on safety objectives
    - Display and update critical performance measures on a 'metrics board' (could be hard copy or on device/screen but needs to be visible and accessible to all)
- Conduct customer satisfaction surveys/interviews/polls – this could relate to internal or external clients
    - Smart production systems will control and monitor the whole product lifecycle, converting traditional products to smart products, creating a digital supply chain that provides all stakeholders with regular status updates to improve decision-making. This information should be harnessed to promote conversations with stakeholders that reveal the full extent of any decisions, changes and their impact (supporting task meaningfulness).

[37] https://www.quantumworkplace.com/future-of-work/performance-management-in-manufacturing
[38] https://www.huronlearninglab.com/resources/articles-and-industry-updates/insights/october-2017/hro-shift-huddle

6. **Sustaining change** – What culture and mindset are necessary for ongoing competitive advantage?

In contrast to price points, technology or products, it is difficult to replicate an organisation's culture. A 'healthy' organisational culture is at the heart of competitive advantage enhancing workforce recruitment and retention, productivity and customer loyalty (Aileron, 2017). Trust[39] is a fundamental building block of 'healthy' culture leading to employee innovation and creativity (Scharf & Weerda, 2022). According to Scharf and Weerda (2022), trust can be fostered by management/leadership role-modelling:

- Reliability (accountability to deliver)
- Acceptance (respecting others' views, habits and backgrounds)
- Openness (expressing ideas and emotions, asking questions freely, willing to receive feedback)
- Authenticity (creating team rituals that encourage personal expression).

Drawing on neuroscience research, evidence suggests part of competitive advantage is about leveraging positive emotions (Cable, 2017[40]). 'Seeking' or the urge to seek, is one of seven core emotions[41] (Panksepp, 2010) and it helps people be curious, explore boundaries of what we know, and look for resources and the new. It is associated with feelings of expectancy and an element of surprise which releases dopamine, a 'happy hormone' (Westlund, 2016[42]).

> The seeking system is
> *…often known for prompting curiosity and exploration and giving rewards…* [and] *is probably the most important brain engine for creativity.*
>
> (Panksepp, 2019)

Being playful and curious are at the heart of innovation and businesses can help activate the seeking system of their employees and harness the associated benefits by[43]:

- Creating environments that are unique, interesting and challenging (provide novel experiences; could involve a change of physical location or development of a new skill)
- Understanding an employee's strengths (use these as an 'ignition switch' to drive enthusiasm and motivation)
- Encouraging employees to investigate problems or areas of interest and interact with others (give them freedom to pursue these/allow space for experimentation – e.g. allocate 20% of time to focus on aspects of interest outside of their regular job)
- Promoting and personalising the 'why' of work (allow individuals to see the cause and effect of their actions, relates to task significance)

Experimentation and problem-solving are required to capitalise on technology adoption and play key roles in organisations developing a continuous improvement mindset and building a learning-to-learn capability, a principal feature of lean production (Saabye, Kristensen, & Waehrens, 2022). However, to be effective, the problem-solving needs to be intentional, systematic (see Figure 10) and with active participation from employees (Mohaghegh & Furlan, 2020; Saabye et al., 2022;

[39] Also see Section 5.
[40] https://www.youtube.com/watch?v=Thfm3pTtymQ
[41] Others are play, lust, care, grief, fear, rage.
[42] https://www.youtube.com/watch?v=TzdPQ13-KGE
[43] Cable (n.d.) https://bigthink.com/thinking/stimulate-brain-seeking-system/

Tortorella, Giglio, & van Dun, 2019). Some have suggested reconceiving lean as a learning system rather than a production system (Powell & Coughlan, 2020).

Figure 10: Characteristics of different problem-solving approaches

Intuitive ('System 1 thinking')

- Automatic/non-conscious
- Low mental effort
- Fast - use prompt remedies/quick fixes
- Driven by instinct and relies on previous experience
- Helpful for short-term success/temporary solutions

Systematic ('System 2 thinking')

- Conscious
- Effortful
- Slow
- Driven by logic, analysis
- Use of scientific method
- Address root cause - often result in better quality and more robust solutions

Based on Kahneman (2011); Mohaghegh and Furlan (2020)

In addition to systematic problem-solving, Saabye and colleagues (2022) also identify the following requisite learning-to-learn capabilities critical to successful Industry 4.0 adoption:

- Leaders are learning facilitators – reliant on degree of self-awareness and ability to critically self-reflect, ability to be humble and ask insightful questions, coach and develop others to learn and problem-solve.
- Leaders foster a supportive learning environment – employees feel safe to fail, seek and give feedback, explore lessons learned.
- Organisational learning scaffold – leaders develop and train others through deliberate learning and problem-solving routines (e.g. coaching[44], A3 thinking[45]) to apply systematic problem-solving and become learning facilitators themselves.
- Industry 4.0 knowledge – Understanding of gap between the current and desired state, having prior understanding of the problem's history, context and previous attempts to solve it.

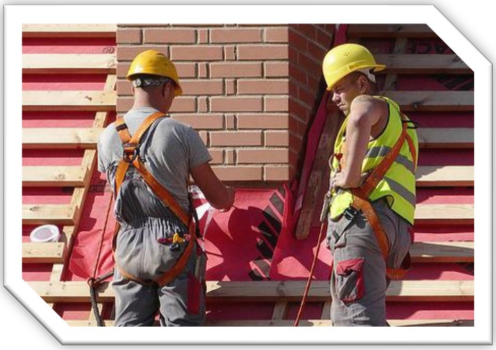
Learning organisations are those:

> *where people continually expand their capacity to create the results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together*
>
> (Senge, 1990, p.3)

[44] https://hbr.org/2019/11/the-leader-as-coach
[45] https://leanconstruction.org/media/learning_laboratory/new/old/TDC-CH40-A3%20Thinking.pdf

Complementary to this, McNally (2021)[46] identifies the following strategies to promote learning at an organisational level:

- Storytelling and role modelling by leaders that learning is important and a long-term approach
- Investment in learning programs, reskilling programs and explicit expectations on time spent learning
- Driving a culture of learning and language of learning (i.e. becomes instinctive to ask 'what are we missing', 'how can we do this differently'?)
- Creating psychological safety where employees feel comfortable to ask questions, share ideas and take risks and these are rewarded
- Formalise capture of learning outcomes (learning loop) and continuous improvement to ensure it is taking place.



If you can enlist other people around you—it could be peers, it could be your manager, it could just be friends that you have in your office—in your learning and to hold each other accountable for what you're trying to work on, that actually goes a long way to ensuring the success of the learning. Part of that is we're all just better when we have an accountability buddy. But part of it is when you're transparent about what you're trying to learn or trying to work on, other people start noticing it more and can give you more helpful feedback

(Smith, 2021[46])

[46] https://www.mckinsey.com/business-functions/people-and-organizational-performance/our-insights/building-a-learning-culture-that-drives-business-forward

Conclusion

We note that frameworks serve as a general rule of thumb and that individual differences can influence which combinations/degrees of factors are most effective at achieving productivity and wellbeing outcomes. For this reason, the value of understanding, communicating and consulting with individual employees regularly cannot be emphasised enough.

To this end, it is also useful to reflect on:

- What motivated employees to join your business? Is this being realised in their current work?
- Are they happy? Has their behaviour changed?
- What are their longer-term career and life aspirations?

Lastly, we acknowledge that there are many models, frameworks and systems (not addressed here) that can be applied to this subject matter. These include innovation models[47], high performance workplaces[48], lean production[49], agile management methodologies[50] and design thinking[51]. These are valuable concepts that apply alongside those discussed here.

[47] e.g. Veiga, Figueiredo, Ferreira & Ambrosio (2021). The spinner innovation model: Understanding the knowledge creation, knowledge transfer and innovation processes in SMEs. *Business Process Management Journal, 27*(2), 590-614
[48] https://www.gallup.com/workplace/269405/high-performance-workplaces-differently.aspx
[49] https://www.leanproduction.com/
[50] https://www.forbes.com/sites/stevedenning/2016/08/13/what-is-agile/?sh=1e70d93726e3
[51] https://hbr.org/2018/09/why-design-thinking-works

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