In Control With Higher Education Through Work-Based Learning

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This study examines the possibility of higher education curriculum at work within the role of an autonomous mine controller. Advances in technology, skills currency and work demand in autonomous mine control rooms have contributed to a resources gap in the domain. Assessing the academic validity of the role can provide an opportunity to lead the way in work-based learning. In reviewing the application of higher education degrees at work, the paper also examines new methods of delivery, such as gamification, to supplement what is being learnt in the workplace and motivate the learner to increase their knowledge. Qualitative organisational analysis reveals work-based learning in the control room is similar to that which currently exists in university curricular in fields such as engineering and management. It is suggested that the changing pace of technological advancements could see an end to (or at least slow down) of several traditional university degrees, and an increased application of adult learning principles through blended studies and work-based curricular.

Keywords: work-based learning, technology, autonomous control rooms, higher-education

INTRODUCTION

How is the Australian mining industry providing opportunities for employees, or potential employees, to gain skills in the digital worlds of Industry 4.0 and Industry 5.0? Is it the responsibility of mining companies to consider training and development opportunities? And, how will advances in technology add to a new pedogeological framework in the future of these industries?

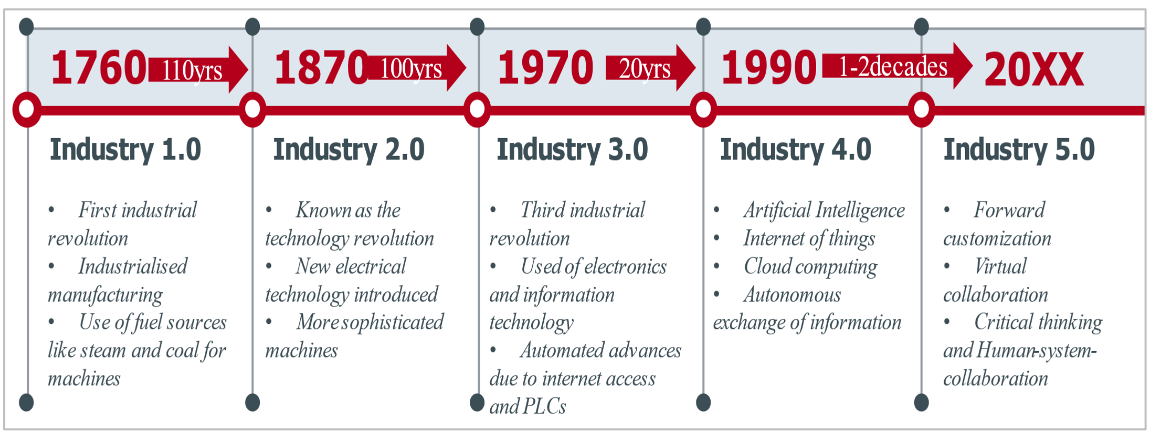
Perhaps what needs to be examined first and foremost within this paper is the term ‘good work design’. Understanding the role descriptions and task requirements of employees expected to work with new technologies is one step in good work design, adding clarity and understanding when trying to map a curriculum to suit. If we want our students to gain practical skills and knowledge they can take from formal education and apply in the workplace, we need to understand what those skills and knowledge requirements are. Designing education for skill sets that may not yet be defined or even exist will be difficult, which is why a review of the current traditional higher education approach should be done. We must challenge the current approach to be more flexible in order to meet the continuous changes demonstrated through new technologies.

Whilst this paper does not cover research in the field of job design for the future worker, it does discuss the role of a particular occupation within the mining industry, that of the mine controller. This role has been selected because it has changes along with technology and adapted over time to suit poorly integrated technology solutions. It could greatly benefit from a change in training and education framework. The role of the mine controller is relatively poorly understood, and the researcher has not been able to find a clear definition of the role. However, it has formed the basis of other research carried out by the current author, and combined with practice-based research, discusses the application of innovations and education within the occupation.

In the last decade, the Australian Mining Industry has only begun embracing what is known widely as Industry 4.0, or the 4th industrial revolution. This term references an industry with a trend toward automation, AI, cloud computing and the Internet of Things (IoT) (Supply chain game changer, 2021). The major players in Australian mining industry were just starting to emerge from a peak in employment, production and growth as they entered Industry 4.0 with a vision to become innovators. Rio Tinto was leading the way, launching the organisation's 'Mine of the future' initiative in 2008, highlighting their ambition to be 'the largest owner operator of Autonomous Haulage' (Bratu, 2018, p.1) becoming the first mining company to begin deploying autonomous trucks .

Figure 1 demonstrates that this announcement from Rio Tinto came almost 2 decades after the beginning of Industry 4.0, so despite leading the way for mining, in the rest of the industrial world, the mining industry could be seen as 'laggards' or 'late majority' on the diffusion of innovation curve developed by EM Rogers in 1962 (LaMorte 2019). What is also evident by the industrial revolution timeline is that advances in innovation and technology, and changes to industry, are accelerating faster than previously observed.

FIGURE 1
INDUSTRIAL REVOLUTION TIMELINE (CHIRGWIN, 2021)



Questions have been raised as to the advances in technology, including automation, artificial intelligence, and the effect on employment in Industry 4.0 and beyond. Due to the relatively slow uptake of automation and technology in the mining industry, it is advantageous to review current literature from other industries to assess the effects and changes to jobs as a result of technological advances.

The mining industry itself appears to have begun to move beyond considerations solely based around monetary and production gains within Industry 4.0, and has perhaps realised the necessary consideration of the transformative effect that the digital world will also have on shaping the workforce in the future (Deloitte, n.d). If organisations aren't already applying these considerations, they will need to.

In examining the implementation of autonomous haulage in mining, two roles have been revealed to bear the brunt of the change: mine controllers and the equipment operators. This paper discusses the former, though the same principles may also be applied to the latter.

The intention of this paper is to get industry thinking of a more sustainable framework for technology integration, with the consideration for humans in the foreground. It is believed that along with the advances in technology will come a demand for different skills to be integrated with existing communities of practice, and the only way for the education system to keep pace with the new technologies will be via a drastic shift in current pedogeological models.

By using advances in technology to our advantage, we may be able to mitigate our vulnerabilities in the current skills shortage through a framework that embraces and combines simulation, gamification of learning, lifelong learning, and work-based learning models.

HYPOTHESIS

To establish the hypothesis of this current paper, the following research questions have been proposed. Each hypothesis (H) is assigned a corresponding research question (RQ):

RQ1. *Is the current education program for mine controllers a sustainable framework to propel industry into the digital world?*

H1.1 *Mine controllers already apply methods of lifelong work-based learning through communities of practice that could be tailored to suit a higher education.*

H1.2 *Future workers in mining automation control rooms will benefit more from interactive learning activities such as work-based practical experience than from more traditional passive, instructor lead training.*

RQ2. *Is the traditional higher education pedagogical framework suitable to meet the demanding changes of technology innovation?*

H2.1 *The traditional pedagogical framework for higher education will need to be adjusted to include work-based, experiential and life-long learning.*

H2.2 *Drastic change is required to meet the changing pace of technological advancements which could see an end or at least a slowing down of several traditional university degrees, and an increased application of adult learning principles through work-based curricular.*

RQ3. *Are there ways to use advances in technology to our advantage when considering training mine controllers in automation and other digital technologies?*

H3.1 *Gamification will supplement what is being learnt in the workplace and motivate the learner to increase their knowledge.*

H3.2 *Simulators/other online learning or eLearning methods will become more prevalent as a tool for learning.*

METHODOLOGY

Through grounded research (Potter, 1998), this study can practically apply the constructivist paradigm (Creswell, 2003) in addressing the real-life participants view of work-based learning in the digital world. The current study considers the implementation of new technologies through Industry 4.0 to Industry 5.0 and beyond as a theoretical foundation, and new methods of training with applied technology, coupled with work-based learning methods, are identified in the application of higher education degrees within work. A brief application of each of the topics and the methodology of the study appears below.

DATA AND METHODS

The investigation begins with a literature review to assess current practice within training and education for the future of work, the application of work-based lifelong learning methods and the integration of new technologies as a learning tool. This is done using qualitative data collections methods such as interviews, observation and document reviews. An examination of the current curricular available to mine controllers is conducted assessing available tools for assessment and delivery.

In addition, observations of the classrooms were made where the current vocational education training (VET) occurs for mine controllers, and participant observations were made in the control room for a mine running a fleet of both an autonomous and manned haulage. Supporting the observations, semi-structured interviews were conducted with existing mine controllers and lecturers delivering Certificate II in Working In An Autonomous Environment, and Certificate IV in Mining Automation And Control Room Operations. Surveys were also sent out to 5 control centres with the intention of reaching more than 100 controllers. Half this number responded positively and only 23 controllers completed the survey due the nature of the work and long hours on-shift. Also a limit of surveys (Lazar *et al*. 2017), the targeted questions may have missed more in-depth analysis, and where further responses were requested, only a small number of controllers chose to take the time to elaborate. For this reason, the data examined comes from the semi-structured interviews, as their nature allowed the participants to open up, enabling deep insights into both the delivery of the vocational education courses as well as on everyday work practice and learning of the autonomous mine controllers.

Semi-Structured Interviews

Interviews were conducted at a time and place that suited the participant, including over the phone, in a lunchroom, in the workplace and at a coffee shop. In all, 10 semi-structured interviews were conducted. The participants included 2 lecturers responsible for delivering the VET courses, and the other 8 were mine controllers. The benefit of conducting the interviews at the workplace was that they could be paired with observations, and the researcher could then expand on the insights received through this collection method, clarifying both what was being observed and what the interviewee was trying to convey (Lazar *et al*. 2017). The interviews have been anonymized and the small number seems sufficient to gain qualitative insights into an exploratory research study. The ability to ask theoretical questions in semi structured interviewers allowed for interpretation and insight for *H1.2, H3.1 and H3.2*

Literature Review

A literature search on mining control room operations began in 2013. This was later expanded to include a search of literature on the topics of human systems integration and training for control room operations. In early 2020, the researcher began gathering and reviewing literature on learning models and relationship between technology and learning. Despite an extensive search through sources for peer reviewed journals (including Science Direct, Wiley, Emerald Insights, Taylor and Francis, Ebscohost, Sage and Elsevier), it is apparent that the review could have included quite a number more articles, particularly in some older fields of research, such as learning models. The research was initially limited by the scarcity of peer reviewed articles on technology and human integration in mining or control rooms. However, the author of this paper notes that interest in this area is increasing, highlighting the importance of the current topic of research. The literature review also examines the hypotheses by engaging in a more practical and industry-specific approach through applying and reviewing company policies and procedures, industry journals and current curricular available to autonomous mine controllers (or prospective controllers).

To guide the literature review, the concepts within the research and hypothesis were considered and the following concepts were key to the searches and analysis:

- Experiential/work-based learning
- Curriculum at work
- Higher education and work
- Training for mine control automation
- Future workers in automation
- Human systems integration in mining automation
- Technology as a tool for learning

Workplace-Based Research

Triangulating the findings of the interviews and the literature research, workplace-based research was conducted during the observation of a control room as a participant observer, and the observation of classroom delivery. This research method aligns to hypotheses H1.1, H1.2 and H2.1, where, unlike traditional research, workplace-based research (or as Zuber-Skerritt and Perry [2002] describe it, action research) incorporates traditional research paradigms and 'collaborative and participatory' research to benefit both the organisation and the body of knowledge being researched (Zuber-Skerritt and Perry, 2002). The qualitative approach of this research is appropriate for the focus on how certain technologies impact employees. Much of the interviews and observations will deal with subjective areas of human emotions which don't have specific measurements and therefore can't be quantified (Sekaran, 2003).

RESULTS

Technology and the Future of Work

This paper has already introduced how rapid changes in technology are being felt in mining and society as a whole. The way we work, the way we learn and how we live and communicate are all being challenged with technological advancements. New technologies are allowing companies to run more efficiently and safely, whilst effectively increasing profitability (Jones and Smith, 2003). To increase these profit margins, organisations must plan all factors into the opportunity assessments for the integration of technology, including understanding the technology itself and the expected outcomes and benefits, risks along all parts of the value chain (not looking at one system or department in isolation), organisational structure and design, as well as the focus of this study, the human factors (Jones and Smith, 2003).

Finding the balance in successful systems integration can be challenging, but getting it wrong could be worse, as Bill Gates points out,

> "The first rule of any technology used in a business is that automation applied to an efficient operation will magnify the efficiency. The second is that automation applied to an inefficient operation will magnify the inefficiency" (Gates in Tracey, 2021, para.34)

One might ask why focusing on humans is important. After all, doesn't automation replace the need for humans? The current paper focuses on how implementation of technology can affect the role of the mine controller and what can be done to ensure its successful integration. Whilst the researcher was unable to find any literature on this topic specifically, a more general search of future work sentiment revealed a view that low skilled, repetitive routine work is more likely to be replaced by automation, and higher skilled work or work that involved soft skills such as creativity or those requiring human emotion may increase (Biffle and Martin, 2020). Autor and Salomons (2017) provide similar findings in their research on production growth versus employment; "rising productivity has not diminished aggregate labour demand but has yielded skill-biased demand shifts." (p.1) Raine and Anderson (2017) question whether "well prepared workers (will) be able to keep up in the race with AI tools", and their findings in their report for the Pew Research Centre in US found that many people believe that, in order to keep up with changes in technology, employees will be required to train and develop new skills for life. Also, the majority of respondents in the Pew report felt that new educational training programs would be required as a result of new technology, with a 'hybrid model' of learning that includes soft skills and capabilities that could be difficult to teach in large numbers (Raine and Anderson, 2017). This was also the observation of the current researcher in the classroom and in the control room, and these findings correspond to responses from lecturers in charge of delivering the pilot program for the Certificate II Working in an Autonomous Environment and the Certificate IV in Mining Automation and Control Room Operations.

The researcher was also unable to find any literature that contradicted the idea that automation and technology would change the way we work rather than completely eliminate all human jobs, although there is some debate on how that will change and what jobs would continue as they are. This change will require deeper understanding of the human factors issues associated to the introduction of new technology, and how the human systems integration (HSI) will be applied.

One of the most significant and talked about changes noted in the mining industry is the deployment of autonomous haulage and the re-deployment of low-skilled operator roles. Industry claims that the individuals in these roles will not be made redundant, rather given the opportunity to re-skill (Smyth, 2019). What hasn't been made clear is the training and development pathway being offered to these employees. One suggestion is that some of the operators will be able to take up positions within the mine control room as autonomous mine control operators, a role which has been significantly overlooked in the past and has evolved in an organic unplanned fashion, making it difficult to create an easy and clear pathway for training within the role. This has placed a focus on the taxonomy of that role within the current study, and raised question as to the educational approach to training new workers. To understand what is required to prepare for the rapid rates of change resulting from new innovations and technologies, the theoretical discussions around the future of work need to be solidified into a strategic plan. Research has shown that inequality is on the rise and the "best-educated capture an increasing share of income and wealth" (Biffle and Martin, 2020, p.12). Sekaran (2003) states that "Managers with knowledge of research have an advantage over those without" (p. 11).

The upheaval that is beginning to be felt by advances in technology could be compared with sentiments from Industry 2.0. In 1948, toward the end of Industry 2.0, and as a result of mass production lines and the effects of World War II, an initiative known as the Marshall Plan (officially called the European Recovery Program) was introduced to rehabilitate economies in Europe and relieve the nations from the feelings of 'devastation and hopelessness' (Ellwood, 2006, p.19). In preparing for the future of work, we may require our own 'Marshall Plan'. A plan significant enough to redefine work as we know it and impactful enough to support current and future workers to successfully transition with new skills and an education reform to suit.

Current Pathways and Motivation

The constantly evolving nature of technology is causing a need for frequent re-skilling or up-skilling of employees. Mine controllers are already demonstrating adaptability and are continuously re-skilling with the introduction of new technologies. Mine controllers have been silently absorbing poorly integrated technology systems for decades (Li *et al.* 2011), but until recently, have largely gone unnoticed, with little or no consideration shown to them. It is perhaps due to the move to city-based control centres (Mills, 2010), or a skills shortage (Deloitte, nd) or even a 'magnification of inefficiencies' as pointed out by Gates (Tracey, 2021), but observations and interviews within the control room showed that, for all intents and purposes, major mining companies *have* begun formulating training frameworks for mine controllers. With the development of the aforementioned Certificate II and Certificate IV, the industry working group, in collaboration with TAFE, made inroads to begin closing a resourcing and skills gap. Through observation and analysis of the pilot programs for these courses (Chirgwin, 2021), it was evident that many experienced mine controllers already had the skills necessary to work in a digital world and demonstrated adaptability to learning and working with new technologies. The pilot program struggled with providing current technology solutions to be used as practical tools due to costs associated with installing new technologies that could be outdated faster than they are approved. The solution was to utilise the tools already available to those learners in their workplace. It must also be considered that, while iron ore is at a record high of (current) $270.17 a tonne (Graham, 2021), the reality is, supervisors in mining operations are keeping all hands-on deck, and there is little time to send employees away for training and upskilling.

When it was delivered to high school students, observations of the pilot program consistently demonstrated the same lack of practical tools as the industry pilot group, however, these students were not able to supplement their educational practice in a workplace with real-world tools, in the way that the professional pilot group could. The lack of these practical tools diminished the objectives of the VET course, which was "facilitating the transition between school and work and providing a highly skilled workforce" (Porter, 2006, p.7). Likewise, the objectives of providing an innovative curriculum for working with automation. For the most part, delivery for both pilot groups was classroom led rote learning with tools such as power point and workbooks.

Through the observations and interviews for this current study, it was evident that some skills were more difficult to teach than others, and whilst digital fluency is expected to be continuously sought after, it was the softer skills that were requested by industry that may benefit from a blended learning approach. PWC's Amanda McIntyre (nd) highlighted these top ten skills predicted to be sort after in the future,

> "Creativity, Emotional intelligence, complex problem solving, judgement and decision making, cognitive flexibility, critical thinking. People management, coordinating with others, service orientation and negotiation." (para.7)

Consistent with observations in the mine control room and findings from discussions with TAFE lecturers, soft skills including cognitive and emotional processes are difficult to measure in assessments. Like training for air traffic controllers, to capture these skills, it is best to apply observation in the workplace (a mine control room) to assess these skills (Oprins *et al*. 2006).

As with changes in technology, we are also seeing a change in our workforce (Thomas, 2009) and in the way people want to learn (or are motivated to learn). On the one hand, employees still have extrinsic rewards, usually financial and external to the work itself, and on the other, intrinsic rewards. These rewards can be linked to those cognitive 'soft skills' and they can also help us understand further motivations for life-long learning.

There are numerous intrinsic rewards organisations can offer their employees, but Blain and Sharot (2021, p.117) have summarised intrinsic rewards to be those that create "a feeling of self-efficacy". Thomas (2009, p.1) described this feeling as "a sense of meaningfulness, a sense of choice, a sense of competence and a sense of progress." Noted through observation and interviews with mine controllers was a distinct lack of intrinsic rewards. Particularly of interest for this current study was the sense of competence. Whilst most controllers observed and interviewed felt that they were competent at their jobs, they did not feel they were receiving due credit for the recognition of their success (Thomas, 2009). Without a qualification similar to those a 4-year university degree, mine controllers do not receive credit or recognition from their organisations for the skills and knowledge they hold. This could largely be attributed to by the fact that for many years, the role of the mine controller has not been very well understood and the calibre (Ballantyne, 2010) of the personnel employed in mine control has been subject to conjecture depending on the mine site in question. The choice between intrinsic and extrinsic rewards may be the motivation that sways employees in today's workplaces to see the benefit of working for one organisation over another (Thomas, 2009).

Supported by technology including fleet management systems, data and reporting tool, robotic machinery, networks, radio communications, sensors and diagnostics, a mine controllers' role is as much a modern technical one as it is a traditional one. Mine controllers must act in a way that meets the mine plan safely and efficiently, much like the role of a supervisor (Ballantyne, 2010). As well, they must display the sought-after behaviours of the future worker; excellent communication, cognitive functioning, situational awareness, autonomy, and critical thinking (Amanda McIntyre, nd). The display of these skills, knowledge and behaviour demonstrates that there may already be a 'curriculum' at work, and that curriculum could be tailored to suit a higher education. Certainly, demonstrated in the observations and interviews of the Certificate II pilot in automation, those students with current experience in a control room felt that they didn't learn much they did not already know, but that they could possibly benefit from the qualities and knowledge that come from higher education above a college level/certificate II or IV. This could also be supported by the earlier assertions that employees that will be sought after in the future will be the ones with higher skills.

In parallel to the constructivist paradigm of this current research, Dumont et al. (2010) convey that one of the most important concepts of learning today is "socio-constructivist" (p.3). They discuss "adaptive expertise" being central to life-long learning, in that "it involves a willingness and ability to change core competencies and continually expand the breadth and depth of one's expertise." (p.3) This ability to adapt to change is constantly being demonstrated in mining control rooms, where controllers have moved from traditionally being an operator or supervisor in the pit, to now carrying out work in a city location. Controllers traditionally ran a fleet of haul trucks manned by operators, but in Industry 4.0, mines are moving more toward fleets of autonomous haul trucks. The adaptability to change can bring to the fore again the ambiguous understanding of the role of the mine controller. The level and amount of change can vary greatly from one site to another, depending on the technology adaptation of that site and task allocation to the controller. Human systems integration across all sites observed by the researcher was consistently poor and confirmed by of the controllers interviewed. Due to the lack of effective consultation and integration approach, controllers as a whole have become very adept at being life-long learners, or "knowledge creating professional" (Van Weert, 2004, p.51) and are always adapting their expertise.

In summary, while controllers may have the self-efficacy to carry out their role as they know it, a lack of intrinsic motivation due to a lack of recognition may contribute to organisations failing to retain those employees, and therefore to fail to fill a skills gap in the future. With predictions of 400–800 million people being displaced by automation by 2030 (Manyika *et al*., 2017, p.11), extrinsic motivation alone may be enough to encourage future workers to seek re-skilling. Of benefit to both mine controllers and industry could be the provision of a level of intrinsic motivational recognition through a blended learning model encompassing higher education and work-based learning.

Technology as a Tool

Not only is the workplace changing, so is the way we learn. New learners are growing up in a digital world where access to learning and knowledge is virtual, instant and often in the form of a game. Traditional and mundane approaches to teaching are not as appreciated when there is access to "new and challenging" experiences elsewhere (Van Weert, 2004, p.59). This new generation of learners share similarities to mine controllers. They are used to multitasking, changing from one task to another, they are goal (or score) focused, responding to multiple alerts, alarms and stimuli; even their tools are similar, with some systems providing a game controller for autonomous equipment. They respond well to other intrinsic motivations that may not be found in traditional roles or traditional learning curricular, and the Certificate II and Certificate IV have not quite met these learners' needs.

As touched on above, in delivery of the new automation curricular at TAFE, there was only low-level technology use outside of the workplace. Students were most engaged when they had the opportunity to engage with technology as part of delivery and assessment, possibly as a result of seeing something new and being motivated to participate in the activities through their 'intrinsic motivation' to learn. Malone's theory of Intrinsically Motivating Instruction (1981) suggests that people will learn more if they are motivated, and this was noted most when activities moved away from instructor led theory delivery. If people want to engage in an activity such as learning without a monetary reward, it is said that they could be intrinsically motivated, and that motivation can fall into three categories: "challenge, fantasy and curiosity" (Malone, 1981, p.335).

Satisfying motivation is the underlying framework found in gamification, and gamification of learning can be supported by technology innovation, including hardware such as wearable devices, and software such as cane platforms (Kim *et al.* 2017). Perhaps most interestingly, implementation of learning and technology through these tools can assist in delivering training for emotive and cognitive skills that can then set people apart from computers in a digital world.

CONCLUSION

The advantage of the model of work-based higher education is the effective implementation and operation of new technology by using new technology as a learning tool. From systems view, integrating humans as lifelong learners and recognising workplaces as partners with learning institutions, organisations can move from reacting organisations to learning organisations, and employees can benefit from learning and receiving recognition homogeneously.

An implication of the current research suggests that neither workplaces nor educators alone can create the necessary competencies, and must utilise appropriate tools to meet the challenges facing learners in the digital world. By partnering to integrate higher curriculums in the workplace, this paper suggests that rather than becoming redundant, educational institutions, industry and the future workforce will reap benefits that allow them to prosper and grow.

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