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8. BEYOND THE TRADE QUALIFICATION

Seeking Higher-order Cognitive Skills

> To transition from a student to a published researcher is a bit like stepping back from the "finish line" and having to re-run much of the race. The challenge here is to accept the thesis is just the beginning, not the end. The true value of research is putting it out there in such a way that the wider population can benefit from what you have learned and can contribute. Being a researcher means you can have a "do-over". Perhaps the next time around you will be just that little bit better. (Arrowsmith)

The mining industry, although a small employer (<2% of the workforce), is an important component of Australia's economy. It makes up 7.7% of GDP and 48% of export earnings, and requires a highly skilled workforce (Australian Bureau of Agricultural Resource Economics and Sciences [ABARES], 2011). The mobile fleet, including ore extractors and dump trucks, is essential in the ore extraction process. Highly skilled technicians are required to maintain equipment to meet high production targets. Comprehensive apprenticeship training of heavy equipment fitters to keep these machines operational is adequate for commencing tradespersons but little is known about how heavy equipment fitters continue to learn and develop the higher-order cognitive and interactive knowledge and skills to service and maintain modern mobile mining equipment. New knowledge and skills are required as new technologies are introduced. The aim of this research was to discover how mobile mining equipment technicians gain the higher-order cognitive and interactive skills necessary to maintain modern mobile equipment.

A qualitative multiple case study methodology was employed to consider the context of working either at the two selected mine sites or in equipment dealerships tasked with providing technical and logistical support to the sites. Research participants were selected purposefully and included 11 heavy equipment fitters, supervisors and trainers who had diverse roles and differed in their experience in the industry. They shared their views and experiences through interviews. Their work practices were observed periodically over a 12-month period. Worksite documents, including procedures manuals, were analysed to understand mobile equipment technicians' skills requirements.

J. Orrell and D. D. Curtis (Eds.), Publishing Higher Degree Research:
Making the Transition from Student to Researcher, 75–84.

Identifying Required Worksite Skills

Mine site technicians have specialised knowledge that relates to the specific equipment used at their site. Mine sites limit the range of machine types (such as dump trucks, wheel loaders and bulldozers) to specific manufacturers and models, which explains the site-specific knowledge required by tradespersons to perform their roles. Therefore, a mine site tradesperson does not need to be familiar with every type of dump truck or wheel loader and their various maintenance requirements; they need be familiar only with the models on which they work. Tradespersons wanting to work in the mining industry require good knowledge and skill in servicing and general maintenance, and a capacity for logical diagnostic practices that can be enacted should common fault-finding methods not resolve a machine breakdown. Specific knowledge of machines, tools and equipment used onsite is learned onsite. Tradespersons customise their generic trade knowledge and adapt it to become highly proficient in maintaining site-specific equipment.

Skill Requirements Needed on a Mine Site

We classify work at mine sites as routine servicing, non-routine but common problems, and non-routine challenging problems. Most work heavy equipment tradespersons undertake on mine sites is routine servicing and maintenance in accordance with detailed service documentation. This work occurs at strict service intervals to minimise the risk of unscheduled breakdowns. Maintenance routines do not necessarily mean the work is easy. Selected personnel who are recognised as site experts at certain tasks through extensive practice undertake tasks such as engine liner pack changes using the tools and equipment available under site conditions. A review of the procedure in the service manual revealed that this task requires high levels of underpinning trade knowledge and skill. Thus, although routine, this is a knowledge-intensive task.

Analysis of maintenance problems that occurred with equipment at each mine site showed that individual machines develop common faults. This is where site-specific knowledge and experience play an important role in maintaining the fleet at high production standards. Site experience leads the tradesperson to check the common issues first, discarding a formal diagnostic process. A deductive diagnostic approach is used only after exhausting the "usual problems" approach. Tradespersons with a capacity to use specialist tools and equipment can diagnose and repair common site-based problems. Although higher level skills are necessary compared with normal servicing and adjustments, these tasks become routine. From this perspective, it is reasonable to deduce that high-order cognitive skills are not necessary for typical problems once these issues are identified and strategies adopted that become internalised as "site-specific knowledge".

Challenges arise when non-routine problems occur. The findings showed that not every tradesperson has the high-order cognitive and interactive skills necessary to deal adequately with these situations. Most tradespersons were satisfied with completing the tasks they were given, despite these being routine, but were willing to take up the challenge of resolving non-routine problems with the machines with technical and peer support from more experienced tradespersons. However, one tradesperson was excited and motived by the challenge of difficult problems, and was capable of undertaking the research needed to systematically diagnose and resolve them. He revealed a much higher level of cognitive skill than his peers. His colleagues indicated his willingness and ability to pass on his knowledge and experience; he showed strong skills in communication, problem solving, self-management and use of technology. Observations at other sites identified a similar pattern of skill distribution among team members. The evidence gathered showed that the current level of site knowledge, skill and work practices are sufficient to maintain the machines to required production standards provided there is a capacity to resolve non-routine problems. We identified three skill levels: technicians who undertake routine servicing and maintenance tasks; those who can perform complex maintenance tasks, including basic problem solving using specialised diagnostic equipment; and those who use high-order cognitive, diagnostic and interactive skills to solve problems and pass on to others what has been learned.

Developing the Required Knowledge and Skills Needed on a Mine Site

The fleet size and the environmental conditions under which the machines operate place diverse maintenance pressures on the personnel operating and servicing them. Tradespersons in each environment become very knowledgeable about individual machines as well as specific machine models and types. Evidence from conversations recorded in diary entries suggests machines often develop "quirks" that distinguish them from others of the same type. Participants attributed these quirks to the number of operating hours within the equipment's service life, how individual operators have treated it, how well it has been serviced and maintained, whether it has been involved in an incident resulting in damage and whether it has been used beyond its designed capacity during its service life.

The mine sites studied have technical and logistic support from equipment dealerships through service contracts in addition to their own technicians. Dealerships have technical support from manufacturers. Mine Site 1 has a dealership facility close by and can call on specific technical or maintenance support readily. Mine Site 2 has some relatively new equipment but does not have an equipment replacement program of a similar nature to Mine Site 1. Mine Site 2 has a technical support contract with the dealership because of the number of machines required onsite. This support is called on to assist with challenging problem solving tasks. Cooperation between mine site maintenance staff and their dealership colleagues ensures sufficient knowledge and skills coverage. Interactive skills to work effectively in teams are essential for the mining environment. Participants' comments and worksite observations showed that tradespersons rarely work alone; they usually form small teams to readily access technical support and to work safely. This practice extends to site tradespersons, who are encouraged to work with dealership personnel where possible to learn specific skills through an informal shadowing or mentoring process. Site-specific knowledge and experience is passed on to dealership personnel, and technical knowledge and experience is passed on to site personnel. Teamwork enables quick, safe completion of required work to allow for the machine to return to production.

The Importance of Site Experience

Site experience is highly valued. Functioning as a heavy equipment fitter requires practical, hands-on exposure to the machines and specialist tools and equipment. This practice is often based on trial and error using detailed technical service documentation. The effectiveness of the learning that occurs is consistent with the elements described by Rogers (1969) and the reflexive practice that follows, linking action with thought (Beard & Wilson, 2006; Kolb & Fry, 1975). A more experienced person mentoring a less experienced tradesperson is one way of sharing site knowledge. Communication between work crew members is encouraged and supported during daily prestart meetings, particularly when non-routine issues arise or have been resolved. This practice places a strong emphasis on interactions between members rather than getting information from reading or interpreting service reports. The location and informal atmosphere of these prestart and toolbox meetings, which occur in the main workshop among the machines at Mine Site 2 and the workshop crib room attached to the main workshop at Mine Site 1, seem appropriate for tradespersons (Le Clus, 2011). This may be a reason for the confidence observed among those presenting during these meetings.

Knowledge with little or no opportunity to practice is quickly lost or difficult to recall. Underpinning trade knowledge needs to be embedded into relevant practical tasks designed to reinforce the importance of general and specific knowledge. A critical incident involving an engine fault at Mine Site 1 supports this. Two tradespersons were assigned this task. They indicated they had received training in using the diagnostic equipment and were familiar with the engine type and its technology, yet they found it difficult to devise a test to resolve the non-routine problem. Later observations of both persons during other work activities, and confirmed by their supervisors in a general discussion, indicated they were competent and skilled in what they had learned through experience (a combination of learned knowledge and practice) but were unable to transfer this knowledge to a difficult novel problem. Their lack of transfer suggests that something more than site experience is necessary for highly proficient performance. Other experienced individuals were able to deal with non-routine problems.

Technical Service Training in the Workplace

Some tradespersons value service training for site-specific equipment provided by dealerships but it has limited impact in developing sufficient knowledge to maintain equipment to high production levels. Dealerships collaborate with manufacturers to develop training programs for those required to maintain their equipment. Pending the introduction of new equipment or technology, dealerships prepare for its release by providing training for those who make the decision to adopt it and those who manage and maintain it. However, dealership-provided service training has not been conducted on either mine site recently. There is a view that the service training programs are not what the sites require, or are not delivered at a useful time. Mine site tradespersons need to know what problems might arise and how they can be rectified. This training is effective if it is practice-based. New equipment entering mine sites is often supported under service contracts (Komatsu Australia, 2013). Maintenance agreements require dealership-trained service personnel to work collaboratively onsite with site personnel. This creates opportunities for mine-based tradespersons to benefit from peer learning and training opportunities at times when skills development is needed. Planning for workforce development must ensure training is not generic but targeted to site-specific needs.

Informal Learning and Interactive Skills in the Workplace

Informal learning is a dominant mode of skills enhancement at each site. Planned informal learning takes place during mentoring activities between experienced site members and those new to the site. Unplanned informal learning occurs as non-routine situations arise. It is influenced by the mentor's and the mentee's interactive skills generated through the experience (De Laat & Schreurs, 2013). The process identifies strengths, weaknesses and benefits in those being mentored and in the mentors and supervisors making decisions on how best to deploy personnel. Peer learning and mentoring in this study is consistent with findings reported by Cairns and Mallock (2011) on the importance of workplace learning as an inspiring and significant dimension of learning.

Reasons for adopting a strong informal learning process appear to be mutual support and reassurance rather than monetary rewards or job security (Evans & Waite, 2010). Informal learning continues beyond the task or activity, as evidenced in diary notes of general conversations away from the workplace, which suggest a reflexive dimension to the learning. When considering workforce development, a strong social network both inside and outside the workplace is important in disseminating site knowledge and experience. This occurs frequently in the workplace through regular toolbox meetings and shared breaks, but less frequently outside the workplace.

Improving the Level of Diagnostic Skill Onsite

Advanced performance depends on individuals who have high-order knowledge and skills. The emergence of these skills appears to be related to high performers' personal attributes. One tradesperson identified with high-level skills reported he had not completed any formal training qualifications since his apprenticeship, but during the interview he revealed he had completed his trade studies at Certificate IV level and not the more common level III. He was dealership-trained and had completed many service training courses prior to working on his current mine site; a pattern consistent with the literature on human capital theory that states current levels of human capital arise from cumulative investment (Becker 1962; Schultz, 1961). The investment this tradesperson has made is general in nature (an apprenticeship in mobile equipment maintenance), with selected dealership service training specific to the organisation's requirements. Current and future employers benefit from previous employers' investment in training (Booth & Katic, 2011). In this case, the tradesperson's level of confidence and self-efficacy appears to arise from a combination of exposure to relevant service training programs and hands-on experience with the equipment, tools and software. He is able to maintain machine performance because he has developed a recursive, systematic diagnostic approach (Andic & Eng, 2012) that ensures he can solve problems readily. This tradesperson generates explicit knowledge, applying concepts in practice to develop expertise (Tynjala, 2008). His willingness and ability to support colleagues is important for both his development as an expert and as a source from whom his colleagues gain specific workplace knowledge (Billett & Choy, 2013).

It is apparent from site observations that even if people of the calibre of such a tradesperson have only limited experience with the technology, they have a level of confidence and initiative to take responsibility and work through problems until a suitable resolution is found. The tradesperson being discussed (Edward) uses the metacognitive processes described by Downing et al. (2008); he reflects on and analyses his experiences to draw conclusions and apply what is known. He has developed beyond "what to do" and "how to do it" to "why do it" and "what have we learned?" He can look forward to "how can we use this in the future?"

Learning in the workplace is an accepted and integral part of being a tradesperson at each mine site, although this was not always made explicit. The five cooperative learning components proposed by Johnson and Johnson (1999) were identified during observations of work procedures at both sites. The resolution of the critical incident involving the premature engine shut-down fault demonstrates the effectiveness of cooperative learning over competitive or individualistic learning (Johnson & Johnson, 2004).

Motivation to Learn

An intrinsic motivation to learn appears to separate tradespersons with higher-order cognitive and interactive skills from their less-skilled peers. Skill shortages would be evident if it were not for the personal drive and commitment revealed by participants Roger, Edward and Andrew. They appear to be motivated by personal satisfaction and self-esteem arising from peer recognition rather than financial incentives. In contrast, the majority of participants were not interested in doing any additional training unless there were financial incentives to do so. Comments such as "I'd probably think about it but that [the financial reward] isn't really happening at the moment" was a common response. Most participants were willing to attend service training provided the incentives were favourable.

Incentives to undertake further personal development through formal training are mainly financial. Long term job security and the ability to earn in a competitive and fluctuating employment market were silences in most interviews. This speaks to the "here and now" philosophy prevalent in research in the mining industry. The work of Robinson and Arthy (1999), and Robinson (2000) suggests that if a learning culture had been introduced earlier in the participants' mining industry careers, those interviewed might have experienced a much broader interpretation of personal development and reward. Only Edward, Roger and Andrew (all with leadership or supervisory roles) revealed intrinsic motivation for ongoing learning, such as increased job satisfaction. The evidence strongly suggests that building a learning culture within the workplace depends on the personal attributes and intrinsic motivation of those with high-order cognitive and interactive skills rather than extrinsic factors.

Balancing Site Skill Requirements

The current balance of expertise is adequate to maintain the fleet to acceptable productivity levels. The literature reviewed revealed the potential for skills shortages but the sites in this study indicated no current skills shortage. None of the sites were seeking additional mobile equipment tradespersons. Thus, we conclude that the current balance of skill levels is adequate to meet the sites' requirements.

The introduction of new technologies may disrupt current skills requirements and supply. Most of the discussion of new technologies in this study is on the technology being built into mobile equipment. Another equally important development is the increase in technology in the diagnostic tools used to solve problems. During discussions about computer use and familiarity with information technologies, all participants indicated they used information technologies as part of their work and were comfortable with them. The problem with using technology is that any lack of skill in using the software or tools only becomes apparent when their use is outside the norm. This limitation is evinced by the lack of understanding of what the available diagnostic tools could do to identify and solve the critical incident involving the engine fault.

In evaluating current work practices and capacity to work with new technologies, the evidence suggests heavy equipment fitters adopt the same strategies they have used in the past; they wait until a new technology arrives, which is when service training is offered. They then develop knowledge and skills to use it as they are exposed to the equipment. The difference between emerging technologies and previous systems is that newer technologies are more complex and more sensitive to incorrect settings. Also, learning by traditional methods such as trial and error takes time; time service personnel and the industry may not have if problems arise early in the introduction of new technologies.

DISCUSSION

The most effective way for tradespersons to develop their high-order cognitive and interactive skills is to adopt a strategy of blending exposure to the equipment with cooperative, informal learning activities. The method of sharing learning through prestart and toolbox meetings further develops individual interactive skills.

Although learning occurs at each site, learning through dealership service training or similar programs is not valued unless it focuses on the needs of the tradesperson for the specific site. The most effective tradespersons have high-order cognitive and interactive skills, and underpinning knowledge and skills gained though formal training, dealership training and a commitment to working through problems to a satisfactory resolution, sharing findings with colleagues and being reflective (Andic & Eng, 2012; Billett & Choy, 2013; Johnson & Johnson, 2004; Tynjala, 2008).

Most work required to maintain high productivity levels is routine despite differences between the nature and focus of tradespersons' work at mine sites (general servicing and breakdowns) and at dealerships (component repair). Each workplace needs the capacity to diagnose and resolve non-routine issues when they occur. This study shows that this is not limited to the level of technology within current equipment. Workforce planning must anticipate a need for personnel who can carry out complex routine and non-routine tasks. The range of required capacities is not found in each individual tradesperson; rather, a mix of skill levels is required, including those individuals who are content to undertake routine work and those who are able to deal with complex non-routine problems.

Mobile mining equipment is evolving and new technologies are entering service in Australia, yet tradespersons in this study continue to adopt strategies used in the past, such as learning on-the-job through trial and error and informal peer learning techniques. The motivation for most tradespersons for developing their knowledge and skills is limited to financial incentives. It appears that only those who have high-order cognitive and interactive skills are driven to learn through personal motivation, satisfaction and the esteem in which they are held by peers. Recognising this distinction is important for ensuring the best skills mix for the worksite and for the development of a workplace learning culture.

This study found three levels of performance that are needed to maintain the current fleet to meet production standards. There are a) technicians who can fulfil required routine servicing and maintenance tasks; b) those who can perform more detailed and complex maintenance tasks, including basic problem solving using specialised diagnostic equipment; and c) those who can use high-order cognitive, diagnostic and interactive skills to solve problems and pass on what has been learned to others. This learned knowledge includes developing strategies to enhance equipment productivity.

CONCLUSIONS

Current trade training at Certificate III level provides a basic introduction to the technical knowledge and skills necessary to work in the mining industry as a heavy equipment fitter. Technicians develop their tradecraft following their pre-service training on the worksite through exposure to the tasks and activities required to service and maintain the mobile equipment used at the site. The research has revealed that knowledge needs to be applied under site conditions to develop skill and expertise. Technical information and resources are readily available from work instructions and service manuals, but learning occurs best in an informal setting, supported by peers. The study has also revealed a need for high-order cognitive and interactive skills. It has shown that tradespersons with these skills become recognised as site experts.

These findings suggest that closer links between registered training organisations (RTO) and worksites, with specific trade training delivered onsite rather than remotely, may be advantageous in developing tradespersons with the desired knowledge and skills. This arrangement would create the opportunity to learn and practice in an authentic environment, increasing the relevance of the certificate learning. If such arrangements are not possible, RTOs may need to simulate the mining context, incorporating the work processes experienced on typical mine sites and in dealerships to improve the relevance of their training. Current trade training and qualifications assume that all qualified tradespersons can, and will, perform all tasks required of them to similar minimum standards on completion of a certificate. This study has shown that tradespersons employed in the mining industry are competent in carrying out routine maintenance to a high standard and that some technicians have gone well beyond that basic level of competence and have achieved a "mastery" level – having high-level cognitive and interactive skills. Such people are needed in the industry.

The mastery skill level is likely to become particularly important because of the introduction of new technology in mobile equipment, and the specialist tools and software required to maintain it. Tradespersons will need to be more proactive in their personal trade skills development as new technology enters service. This may include developing higher levels of cognitive and interactive capacity than are currently held. Participants identified skills gaps in electronics and advanced hydraulics. The deployment of new technologies to improve fuel efficiency, reduce emissions, enhance safety, greater machine monitoring and self-diagnostics will create a need for on-the-job skills development. This capability is not well-developed, as evidenced by the critical incident involving an engine fault. Service and maintenance personnel need the capacity to develop their knowledge and skills to remain current and familiar with innovations in technology to maintain equipment at peak performance levels.

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