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Learning and Development, a vital tool for effective Engineering Asset Management (EAM) in the Australian Mining Industry – A Systematic Review

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ABSTRACT

CONTEXT

The mining and resource industry is well known for high maintenance and production costs, and with this, there is now a high focus on how these departments spend their budgets and the results of their Key Performance Indicators (KPIs). The mining and resource sector is continuously improving and evolving in technology, with a close focus now on maintenance costs and finding sustainable means of production. Highly trained maintenance teams are high-performing, and coaching and training are vital assets in Engineering Asset Management (EAM).

PURPOSE OR GOAL

This paper explores the literature and investigates the relationship between effective learning and development of engineering maintenance teams and the resulting effectiveness in the EAM principles, particularly asset reliability. The intent is to examine the effectiveness of training, coaching, and knowledge transfer in improving EAM.

APPROACH OR METHODOLOGY/METHODS

This systematic review explores high-level journals within the last 15 years accessed via Scopus, Web of Science and ProQuest online databases. A literature review search strategy was developed with five concepts and some limiting factors to include only high-level journals. Search results were processed and refined through a modified Prisma systematic review process, including a thesaurus database search, a deduplication process and finally, a three-person anonymous review conducted on Rayyan. The results were an inclusion list of 12 articles. Further, six articles with background information on asset management, training, and coaching were also studied to add some underlying knowledge to the research.

ACTUAL OR ANTICIPATED OUTCOMES

Emerging themes from the studied literature include learning and development as a critical aspect of improved EAM. This has evolved with most big mining companies realising the need for investment in the education and development of their maintenance teams. Coaching and training are essential for effective knowledge transfer between academia and industry. EAM is a fast-evolving aspect of modern technology that requires upskilling in more advanced asset management maintenance systems.

CONCLUSIONS/RECOMMENDATIONS/SUMMARY

This research will help identify gaps in the apprenticeship and graduate traineeship programmes and how these skills improve adequate asset reliability. It will also recommend how best to bridge knowledge gaps with different stakeholders.

KEYWORDS

learning; development; maintenance; asset; reliability; training; coaching

Introduction

This systematic review follows up on research by the first author as part of a Master's Research Project undertaken for a Master's of Professional Engineering Degree Programme with the University of Southern Queensland (USQ) from 2023. The mining and resource industry is well known for high maintenance and production costs, and with this, there is now a high focus on how these departments spend their budgets and the results of their Key Performance Indicators (KPIs) (Charindeguta, 2024). There is a need to manage maintenance systems efficiently, and skilled maintenance labour is at the centre of these systems. Charindeguta (2024) denotes that high-performing engineering teams ensure the maintenance system is effective and brings improved asset reliability, ensuring better general savings and profits for the business. Investing more in the maintenance system backbone means a skilled maintenance labour knowledge base is needed. Different stakeholders involved in the Engineering Asset Management (EAM) will be consulted as part of the research. According to earlier research by Charindeguta (2024), EAM is an emerging concept that complements the maintenance activities, how they are managed and the associated risks and performance of assets. Maintenance costs take up much of the operational budget in the mining sector, with high spares and maintenance activities costs. In this regard, it is imperative to manage EAM effectively. Learning and development of maintenance personnel is a vital tool that can improve asset performance through effective EAM.

The stakeholders involved in this research include postgraduates, currently enrolled apprentices, prospective apprentices, supervisors, engineering managers, university lecturers and TAFE lecturers. How the mining industry onboards and incorporates postgraduate students and prospective apprentices into their existing work will shed more light on the value addition or lack of knowledge transfer that might exist in this process. Consultations with the tertiary institution will also bring this research to an understanding of the suitability of engineering programs to the current mining industry's needs. This research seeks to investigate the link that exists between learning and development and improved EAM. The main objectives of this research are to identify the link between investing in learning and the development of maintenance teams and the effectiveness of the EAM. The research will also seek to discover if investing in a skilled workforce's technical development will improve their knowledge of EAM and asset reliability. The research will also investigate whether effective learning and development can improve organisational culture and better retain a skilled maintenance workforce. Lastly, this research will also clearly outline any gaps from the literature review, which can be explored and investigated further in future research. Hence, the research questions for this study are as follows: What is the extant knowledge of EAM learning and development in the mining industry? Does it have a measurable impact on the availability and reliability of assets? Does it improve the organisational culture and skilled workforce retention? Does it impact the effectiveness of EAM?

Literature Review Methodology

A systematic review of the existing literature was intensively carried out from January 2024 to May 2024. This focused on setting up search terms with criteria based on the research question. A systematic literature review is the best approach for investigating the relationship between learning and development and EAM. The importance of a systematic review is noted in an article by Borrego et al. (2014), which focuses on the methodologies of systematic reviews applied in the engineering education field. This approach ensures that all the relevant literature is studied and no vital information is left behind. Firstly, a literature review search strategy was formulated, as shown in Table 1, with five main concepts specified. Keywords were identified, and a final search string was developed. This was then used to search the central quality databases, namely Scopus, Web of Science and ProQuest.

Table 1: Literature Review Search Strategy

Key concept #1a	Key concept #1b	Key concept #2	Key concept #3	Key concept #4	Key concept #5	Limiters?
TAFE OR Universit* OR Colleg* OR Industr* OR Compan*	Workplace* OR Industr* OR Compan*	Learn* OR Development OR Coach* OR Train* OR Mentor* OR Induction*	manage* OR maintain* OR mainten*	Mining OR Miner* OR Mine*	Asset* OR Facilit* OR equipment*	**Language:** English **Resources:** journal articles (peer-reviewed) books/chapters theses conference proceedings government reports organisational reports. Business reports, newspaper articles **Sources:** ProQuest Scopus Web of Science

Keyword Definition & Search String

A literature review strategy was developed in this first stage with five distinct concepts from the research question. For each idea, keywords were developed utilising the thesaurus synonym search to ensure all related words were considered. The results were all the keywords, as shown in Table 1. A limit criterion was also set to ensure that criteria, including language, resources, and specified sources, would guide all searches. Figure 1 shows the modified Prisma systematic review map starting with the title, abstract and keyword search resulting in a search string ***(TS=(TAFE OR Universit* OR Workplace* OR Industr* OR Compan*)) AND (TS=(Learn* OR Development OR Coach* OR Train* OR Mentor* OR Induction*)) AND (TS=(manage* OR maintain* OR mainten*)) AND (TS=(Mining OR Miner* OR Mine*)) AND (TS=(Asset* OR Facilit* OR equipment*)).*** It was noted that the search string would vary between different databases because of different search structures in the database systems. A Polyglot Search String Refiner was utilised to search for articles in the databases through the built-in thesaurus search.

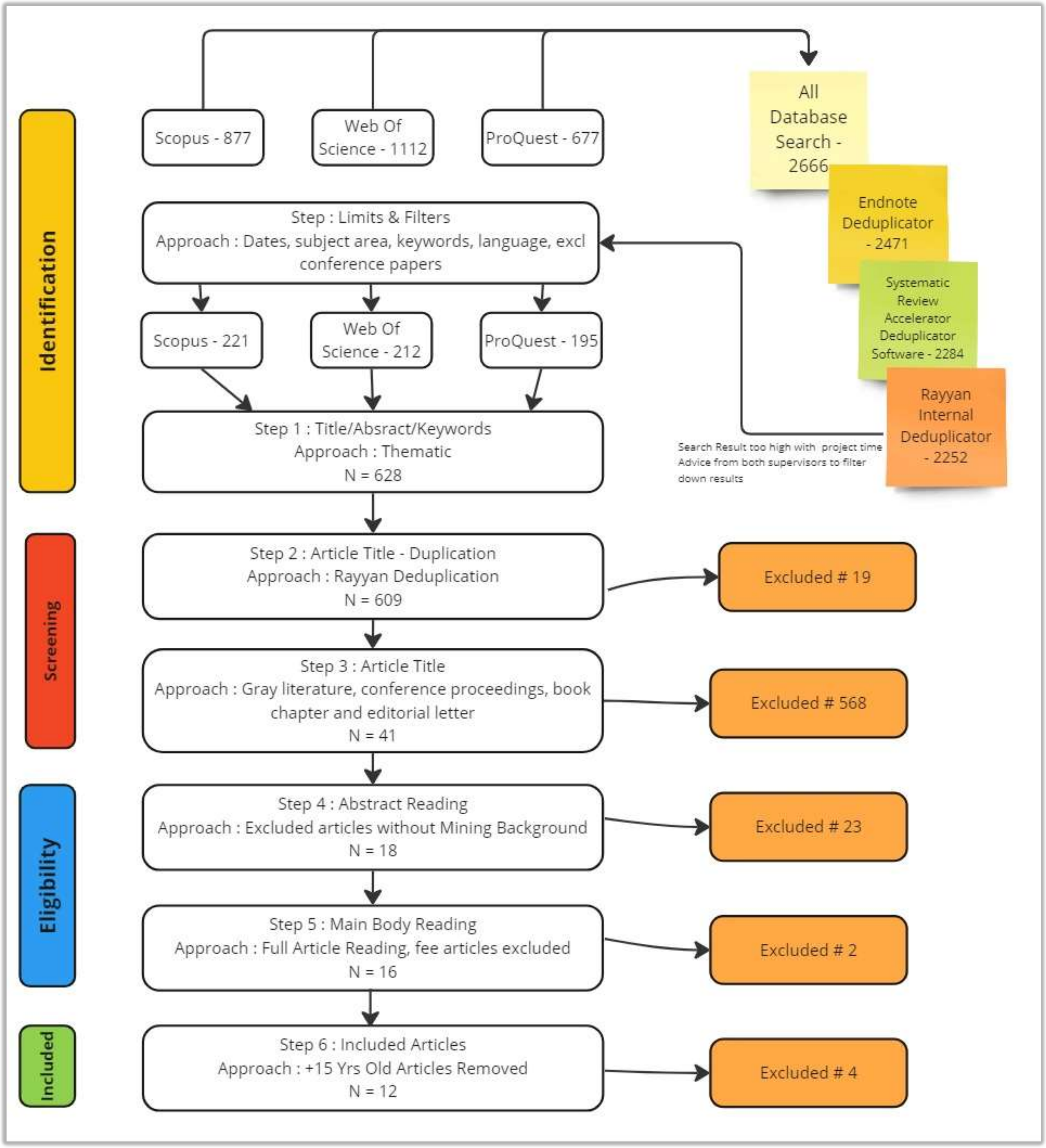

Figure 1: Modified Prisma Systematic Review Map

Source: Modified from Mengist et al. (2019)

Step 1: Article Identification

This initial search after deduplication returned 2252 articles. With consultation from the supervisors and limited time in the initial research timeline, a decision was made to filter the articles further according to dates, subject area, keywords, language, and exclusion of conference papers. This significantly reduced the number of articles to 628. This number could be managed and intensely reviewed within the available time frame.

Step 2: Article Screening

The second stage encompassed the article screening process, where all the 609 search results articles were processed. This critical process started with the search results being exported into Endnote to remove the duplicates, followed by exporting the results into Rayyan, a renounced systematic review system. This system established the first screening criteria based on the article title; the selection approach excluded grey literature, conference proceedings, book chapters, and editorial letters. This process excluded 563 articles, with the remaining 41 articles proceeding in the review process. As part of this phase, research training on systematic literature reviews, research strategies and data collection and processing was undertaken to equip the primary researcher with essential skills to conduct a quality review.

Step 3: Article Eligibility

The third step in the systematic review process involved three reviewers reviewing the abstracts of the 41 articles. This was done online on the Rayyan Systematic Review platform, with each reviewer in a blind review mode to limit the influence of other reviewers' work. The selection criteria were reading the abstracts and excluding any articles that did not relate to the Mining Industry. Once each reviewer had finished their review, an all-inclusive meeting was held over several sections to review the included, maybe, and excluded articles. As part of this step, 23 articles were excluded, resulting in 18 articles progressing to the next step. As part of the eligibility process, the main focus is putting aside the relevant articles with suitable, valuable literature for the research. All 18 articles were sourced from high-quality journals and publishers to achieve this. Two of these articles could not be accessed due to requiring external access from third parties and fees required. The final 16 articles were accessed, studied, and stored as part of the literature review data collection. Online collaboration on Rayyan provided a seamless review process in real-time as the reviewers exchanged insights on conflicting decisions on some articles, which were resolved seamlessly.

Step 4: Article Inclusion

The final step in this systematic review process had the final 16 articles studied and themes analysed. More time and resources were dedicated in this phase to thoroughly examine the included literature and draw some themes and insights on the research. It was also noted that 4 of these articles were more than 15 years old. These articles were studied for reference, but an inclusive decision was made after consultation with the reviewers and supervisors to exclude them from the final literature review. Some valuable background knowledge was considered and added to the emerging themes. Thus, the final number of articles included was 12. As the research broadens, more literature can be included to widen the knowledge base. Future research opportunities can expand the scope of EAM in the Australian industry. This initial systematic review based on these articles can pave the way to note emerging insights and identify potential in EAM.

Emerging Themes

Following this intensive systematic review of the included literature, it can be noted that some common themes co-exist within several articles. An effort was made to classify the four main themes that emanate from the review. These themes include learning and development, coaching and training, knowledge transfer and Engineering Asset Management (EMA). Several researchers and authors create interconnectivity between these aspects to create a compelling and profitable mining enterprise. The main focus was on how well-trained teams are highly effective in performance, improving overall EAM and ensuring a sound business portfolio. At the same time, the maintenance teams are built strong in these environments, ensuring self-actualisation amongst them.

Learning and Development

Beebe (2006), in his paper titled “Experience with Education in Maintenance and Reliability Engineering by Off Campus Learning,” explores how distance learning has been used for industry-based engineers' post-graduate education. This paper, although beyond the time frame scope, is critical as it examines the Monash MRE program, developed in mid-1980, and how it aimed “to equip people with the knowledge, skills and attitudes to improve the life cycle performance of plant assets and thereby improve the performance of their business”. (Beebe 2006, p. 883). This puts the program's objective in line with this research’s goal to find the relationship between the two aspects. Beebe (2006) explores the programme’s evolution, study material, teaching methods, and web-based delivery system. In his study, he also investigated the target market of those studying this program through a questionnaire developed in 2005. Of interest are the findings that the mining and mineral processing industry was leading, with 37% of students taking the programme, followed by defence, manufacturing, and utility sectors among the top five. Surveys were also conducted to investigate what should be included in the MRE courses. A look at earlier studies on the subject matter further puts more weight on the importance of flexible learning. Collaboration is key between the student and the teacher, even though web-based means—this further aligns with my key goal to investigate if learning and development can improve asset management. Ashipala (2021) Mentions that technical rather than academic education would remain the cornerstone of the mining industry. This shows the importance of technical skills harnessed through practical experiences at the workplace. This paper also delves into apprenticeship programmes, in-service training, and the establishment of technical training centres. The notable notion from Ashipala (2021) Is that training and investment in technical knowledge were made to benefit the companies. In conclusion, it can be noted that “Experience with web-enhanced delivery of off-campus learning in MRE shows that improved learning is possible, but significant overall benefits should not be expected initially when compared with paper-based print materials alone” (Beebe, 2010, p. 891).

Coaching and Training

The paper titled “How Inbound Open Innovation Helps SMEs Learn and Improve: Knowledge Transfer from University to Industry through Direct Coaching” by Claire et al. (2018). explores how coaching using academic knowledge improves the innovation of Small and Medium Enterprises (SMEs). The paper looks at a pilot project that studied 10 SMEs, exploring how knowledge transfer was facilitated by direct-on-one coaching between academia and SMEs. A link can be drawn as we relate to another article by Cyrulik and Augustyn (2019), which notes that vocational training enables the development and improvement of specific professional activities or team cooperation. Developing selected skills can significantly improve occupational health and safety. In the mining industry, safety is crucial to personal and environmental protection. Aligning your team with regular training promotes a safe environment and quality (Cyrulik and Augustyn 2019). Further, it clarifies a vital opinion that competence vocational courses significantly impact the quality of human resources. Face-to-face interactions in transferring knowledge are paramount through the coaching provided. According to Claire et al. (2018), coaching supports action learning, which involves using questions to stimulate solutions development—the results. Claire et al. (2018) conclude that coaching is pivotal in ensuring effective knowledge transfer for SMEs. The other article focusing on coaching is titled “Leveraging coaching as an instrument for training transfer: A case of learners in a Fintech Firm” by Ramnath and Vinita (2023). This looks at a study on 47 detainees who underwent coaching in a Fintech Firm. The top findings of this study were that “one-on-one coaching provided them with the much-needed “personal touch” in a post-training environment and customised feedback for the application of trained knowledge.” (Ramnath, D & Vinita, S 2022, p. 2). Conclusively, one-on-one coaching enables more rich learning and experience sharing between individuals. This can be applied practically by setting up a buddy system between skilled tradesperson and apprentices.

Knowledge Transfer

Claire et al. (2018) explore the concept of knowledge transfer. Based on six studies done in SMEs, knowledge sharing is most beneficial for growing SMEs. Knowledge transfer between academia and SMEs should be seamless and aim to improve innovation. On the other hand, knowledge flow depends on the communication processes employed. “Knowledge flow is most likely influenced by four factors: knowledge transferred, source, recipient and context” (Claire et al., 2018, p. 3). Ramnath and Vinita, (2023) define training transfer as applying trained knowledge at the workplace. They state that 20% of the skills and knowledge gained during the training is directly transferred to the job. This direct benefit ensures improved asset reliability and performance. “Knowledge transfer also draws in from building trust between the two interacting parties. “It is necessary to establish the willingness of the donor to share knowledge and clarify appropriate rewards, as well as checking the willingness of the receiving entity to accept” (Claire et al., 2018, p. 3). There is evidence from Claire et al., (2018) to clarify that knowledge transfer between universities and companies exists. However, some gaps need to be filled to make it more beneficial to both the donor and the receiver. Recommendations for tool-based knowledge transfer, including success enables, bottlenecks and barriers, are given. Dyorina et al. (2020), in their paper on " Training for the mining and metallurgical industry based on electronic educational technologies”, mention that one of the main tasks of the personnel training and retraining system is to assess the staff's compliance with job responsibilities. Dyorina et al., (2020) mentions that traditional training systems must be more effective and require innovative technologies based on information and computer technology. Lastly, knowledge becomes insufficient over time and must be replaced with new skills through knowledge transfer.

Engineering Asset Management (EAM)

The concept of EMA is widely discussed by Hodkiewicz et al.(2006) in their paper titled “Education in Engineering Asset Management – Current Trends and Challenges”. They discuss the idea that asset owners are increasingly focused on investing in EAM with a scoped focus on training the maintenance teams. Maintenance teams can be trained in analytical tools such as Pareto Charts, brainstorming, flowcharting, and fishbone analysis to help them assume problem-solving responsibilities. Monitoring of the production process can be done with statistical methods like SPC. The importance of maintenance teams' skills in the overall driving data to plant reliability is critical in achieving improved EAM. “Asset owners are now seeking to improve the level of competencies of their personnel” (Hodkiewicz et al., 2006, p. 31). Most importantly, there is a greater appreciation of the skills and knowledge required to maintain assets effectively. Hodkiewicz et al. (2006) summarised that asset owners now drive asset management with the need to be proactively involved in the underpinning body of knowledge. Hodkiewicz et al. (2006) emphasised that significant improvements in decision-making, teamwork, and communication skills are necessary at all levels of an organisation, not only within maintenance and operations groups. Jardine and Tsang (2013) Assess the importance of the interpretation of asses data and rationalise that unless we can interpret and use such data intelligently, it is of little use; you can be data-rich but information poor. Asset management is also discussed by Dutra and Hupp (2013) in their paper “Asset Management in Mining: A Practical Case on Obtaining Reliable Performance, Risk and Cost Measurements”. In this paper, some investigation was done on asset management in the iron ore mining sector to improve asset performance measurement. In identifying the asset performance metrics, they noted that the human element between the craftsman, scheduler, and CMMS system entirely depended on the person's competencies. In this regard, it is essential to have competent personnel supported by training, learning, and development, perhaps through coaching, as the other literature suggests. In the academic sector, EAM has been taught since 2003 as an underpinning course in the Master of Professional Engineering programme in the unit Asset Management in an Engineering Environment at the University of Southern Queensland. This course constantly evolves with student feedback, industry, and alignment with Engineer’s Australia competencies. Developing and implementing these courses supports continuous improvement in the knowledge surrounding EAM.

Conclusion and Recommendations

The detailed systematic review process narrowed down the essential articles in the Mining Industry. The emerging themes support the hypothesis that learning and development are critical and practical tools for improved EAM. The papers discussed above have paved the way for a better understanding of the core components of this research: learning and development, coaching and training, knowledge transfer, and lastly, EMA. The studies in the papers help in the research to identify the gaps that currently exist between academia and industry. Recommendations are emerging on how to close these gaps. Understanding these concepts helps to link the different ideas together to weave a connection in how learning and development is a vital tool to the effectiveness of EAM. From this review, we can closely link the concepts and note how each is paramount in achieving improved asset performance and reducing maintenance costs. Further studies can be explored in the next phase of the research to investigate the effectiveness of these concepts. Some gaps emerge between the academic knowledge acquired in tertiary institutions and the mining industrial experience and knowledge. Different authors have noted how this concept can bridge these gaps through knowledge transfer.

The following research phase will involve developing the methodology and testing the hypothesis before a mixed-method approach can be used to investigate it. Surveys and stakeholder interviews will be this research's most effective data collection methods. There is a significant opportunity for critical improvements that can be worked on to effectively train, coach, and ensure knowledge transfer between different stakeholders. This will, in turn, improve the overall EAM and maintenance team performance.

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