THE EFFECTIVENESS OF USING LEARNING FACTORIES TO IMPART LEAN PRINCIPLES TO DEVELOP BUSINESS IMPROVEMENT SKILLS IN MINING EMPLOYEES

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Declaration

I declare that this research report is my own unaided work. It is being submitted to the Degree of Master of Science to the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination to any other University.

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Ruramai Sarah Mabaisa Makumbe

…18….. day of …May……..., …2017……

Abstract

The purpose of this research was to investigate the effectiveness of Learning factories in imparting Lean principles in order to build Business Improvement skills of mining workforces.

This study was conducted at a training centre established by a mining company in South Africa. Two groups of participants with employees at two different employment levels were trained at the centre in foundation Lean principles. The Kirkpatrick model for evaluating effectiveness of training was chosen as a tool that can be used to evaluate the effectiveness of this Lean training. This was achieved using before-and-after questionnaires, visual observations and process data from improvement projects identified by the participants.

The results showed that the Learning Factory is effective in imparting the Lean skills across hierarchy levels in a mining operation within a short space of time. Furthermore, all employees arrived at the same overall Lean understanding post training regardless of their starting point. Where project implementation was done, it was found that the participants were able to apply most of the Lean principles in the workplace. A major shortcoming observed was that the main focus was on technical aspects of Lean with little regard for other aspects that contribute to sustainable Business Improvement such as change of culture.

Lastly it was found that while the Learning Factory can assist in building Lean capability in an implementation, the other success factors such as management buy-in and workforce support can enhance this effort. One recommendation is to do a study to determine the interrelated nature of the factors that drive a successful Lean implementation and the role that a change management program like ADKAR can play to maximise success.

Blessing Makumbe, my husband.

For years you encouraged me and told me to study further and while I was reluctant initially, I also had difficulty finding something I would truly enjoy. That was until I discovered Industrial Engineering and how I have enjoyed it!

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Thank you God for the grace to finish.

Blessing Makumbe, thank you for believing in me even before I started and thank you for the support over the years it took to complete my studies.

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Thank you to the mining organisation that allowed me to conduct my research at the centre and the facilitators at the centre who accommodated my study during their training.

Lastly, I do not take it for granted that I completed my studies with funding provided by my employer. Having struggled with financing my undergraduate studies, the support extended to me for this degree allowed me to focus on the core business of learning. I knew that my needs were taken care of and for that I am also grateful.

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1 Introduction

1.1 Purpose of the study

The implementation of Lean in mining operations has been slow and fragmented with different methods of implementation employed by different companies (Nyamarebvu, 2012). In an extensive literature review done by Loow (2015) where he looked at 17 papers on the subject of Lean in the mining industry, he finds that there has not been a case of a “complete” Lean implementation as some of the Lean practices are not suited to mining operations and activities. Various levels of implementation success have been reported to date and according to Loow (2015) there has been no negative results reported though some implementations did not realise any benefits at all.

In spite of all this, the need for a strategy that turns around operations and improves productivity remains paramount. To weather the current storm that mining organisations face, they have to optimise assets to drive maximum returns. As such, the need to ensure Lean implementations are successful and sustainable is ever increasing. There is a clear requirement to build Lean capability across all levels of the workforce. According to Deloitte’s (2016) report on the top ten issues that mining companies would face in 2016 and beyond, they site that there is a clear requirement to drive operational excellence in mining operations. They go on to suggest Lean methods as a tool that can be used to achieve this (Deloitte, 2016). There is a clear requirement to build Lean capability in mining employees to support this strategy going forward. This Lean capability should be embedded in the workforce and applied consistently in order to drive meaningful business results. One such tool that has been used successfully in effective competency development in employees at all hierarchy levels is the Learning factory (Abele, et al., 2015). A mining company in South Africa has recently developed a training facility that uses a Learning factory to teach Lean skills to mining employees.

Therefore the purpose of this research report is to investigate how effective the Learning factory is in imparting Lean skills in order to build Business Improvement capability to employees at mining operations. The investigation will also explore how well the content is understood and interpreted across hierarchy levels.

1.2 Research background

In recent years the global mining industry has been under significant pressure and this has resulted in mining stocks struggling as shown in Figure 1.1.

Figure 1.1: Decline in global mining stocks since 2008 (Bloomberg, 2016)

The main factor contributing to this downward trend is lacklustre demand which has resulted in sharp decline in commodity prices (Deloitte, 2016). The situation has been worsened by rising operating costs, labour difficulties and reduced productivities (Deloitte, 2016) . A bleak picture is painted by Deloitte in their mining industry analysis report where they look at the drop in China's growth rate, weaker commodity prices and the impact that this has had on falling share prices, revenues, profits and rising debt levels (Deloitte, 2014).

Deloitte (2016) further highlights that another internal factor affecting mines is that the quality of ore has declined with time as mineral reserves get depleted. As a result, most mines are extracting low grade deposits which come at a higher cost. Investing capital in these deposits will result in lower returns as there is less metal content relative to higher grade deposits.

The strategy taken by mining companies has changed significantly from being growth driven to being value driven and the search for value has extended to cost reduction through organisational redesign, rationalising portfolios through disposal of assets and optimising existing assets to drive maximum returns (Deloitte, 2016). The latter has led to a drive to adopt Lean principles developed in manufacturing and resulted in massive operational performance improvements in that industry (Nyamarebvu, 2012); (Deloitte, 2016); (Loow, 2015). The same success has also been realised in the health sector (Loow, 2015). These Lean principles have been adapted for use in mining operations with the intention of obtaining a step-change increase in performance (Loow, 2015). This source further elaborates that the adaption of the tools to mining is considered to be crucial in addressing the inherent differences between manufacturing and mining. This research looks at how Lean implementations by mining companies can be more successful and sustainable by focusing on building capability to ensure employees are competent and can apply Lean methods efficiently.

1.3 Research motivation

While Lean implementations in mining have been slow and fragmented, the industry is making inroads into incorporating Lean principles. The industry as a whole is yet to realise the levels of success that are comparable to manufacturing and health care (Nyamarebvu, 2012). Most widely available literature on Lean in mining describes case studies on where Lean has been implemented, which Lean tools were implemented and the approach taken (Hattingh & Keys, 2010); (Castillo, et al., 2014); (Nyamarebvu, 2012); (Sanda, et al., 2011); (Loow, 2015); (Dunstan, et al., 2006); (Nadeau, et al., 2015). There are also conceptual studies that look at how Lean can be implemented in a mining environment (Yingling, et al., 2000). With the current challenges in the mining industry, more organisations continue to look at how Lean principles can be used to bring about improved sustainable operational performance. However, there has been no focus on how sustained competency development can be introduced in these operations in order to support the Lean implementation.

There appears to be very little research on how an organisation can build Lean capability in a mining workforce specifically. Given that Lean principles originated from manufacturing, one could start by looking at how that industry trains and builds Lean capability. Learning factories have shown success in building capability across hierarchical levels in manufacturing. They have also been found to be effective in imparting Lean skills rapidly in volatile business environments where companies need to quickly adapt to new market conditions in order to survive (Abele, et al., 2015). Learning factories have been this successful because they rely on experiential learning which according to research, results in improved retention and application possibilities that are more superior to traditional teaching methods like lecturing (Cachay, et al., 2012).

There is a need to investigate if training mining workforces in a Learning factory will result in similar success. This research will look at the effectiveness of using Learning factories in imparting Lean skills to mining workforces. It will also consider the effectiveness of this tool across the hierarchy levels in a mining organisation.

1.4 Assumptions

Assumptions made are:

1. At the time of doing this research, no other known Learning factory for mining companies has been set up in South Africa.
2. Participants will be supportive, keen to take part in this exercise to get the best results.

1.5 Research Questions

This research will seek to answer this key research problem:

Is the Learning factory an effective way of imparting Lean principles to develop Business Improvement capability in mining employees?

In addressing this research problem, the following research questions will be answered:

1. Is the Learning factory an effective way in imparting Lean principles and methods to mining employees?
2. How effective is the Learning factory in imparting these skills across different hierarchy levels in a mining operation?

The methods for evaluating effectiveness will be discussed as part of the Literature Review (Chapter 2) and Research Methods (Chapter 4)

1.6 Research Objectives

The main objectives of this research are:

- Determine how well the Lean principles are understood after being taught through the Learning factory
- Determine how well they are applied in the workplace after they have been taught
- Determine how well they are understood and applied across hierarchy levels in an organisation

1.7 Report Layout

The research approach consisted of a review of literature around Lean implementations in mining, Learning factories and measuring effectiveness of training. This is followed by the case study context before the relevant research methodology and research method followed is given. Results are presented thereafter. Discussion of the results then leads to a conclusion of the research subject. This approach is depicted pictorially in Figure 1.2.

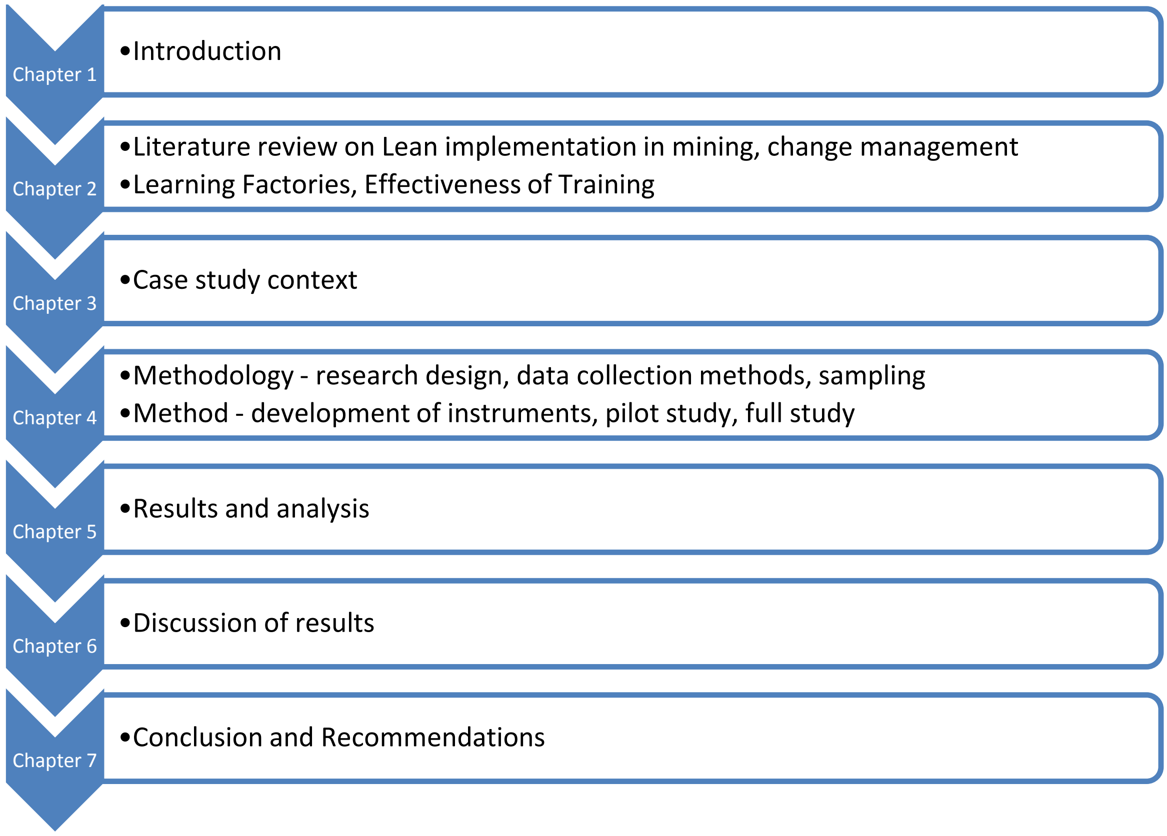

Figure 1.2: Research Layout

2 Literature Review

2.1 Introduction

This section summarises the literature review that has led to the identification of the research problem. The first step in the literature review was to consider a Lean framework for mining and to do this, the history of Lean and Lean principles were explored. Once the Lean framework was identified, the current state of Lean implementation in mining was studied to identify benefits, challenges and success factors for Lean implementations. From there, Lean tools for introducing Business Improvement skills in mining were identified based on practical case studies. Change management in Lean implementation was then investigated. Lastly the use of Learning factories to teach the Lean tools identified in order to build Lean capability was considered along with training effectiveness.

2.2 Lean framework for mining

2.2.1 History of Lean

While Lean has its' origins in manufacturing it has evolved and expanded into other contexts such as services and health care (Bicheno & Holweg, 2009). According to the Lean Enterprise Institute (2016), Henry Ford was the first person to integrate an entire production process in 1913. Taaichi Ohno from Toyota gave the crucial impulse towards developing the Toyota Production System (TPS) that was capable of economically producing a large variety of products in small volumes (Bicheno & Holweg, 2009). TPS was able to achieve this by looking at flow of product through the entire process. According to Womack et.al (1990), TPS gave birth to the Lean principles and methods. From TPS other improvement philosophies have evolved such as Theory of Constraints, Six Sigma and Lean Management (Hattingh & Keys, 2010); (Nyamarebvu, 2012). The principles from TPS and their contribution to Lean will be expanded in the next section.

2.2.2 Principles from Toyota Production System (TPS)

In the work done by Liker (2004), he describes the principles coming out of the Toyota Production System using a 4P model. Contained in this model are the

14 Toyota Way Management Principles. Figure 2.1 shows the principles in the 4P model that Liker developed. The 4P's stand for Philosophy, Process, People and Partners and Problem Solving. A high level description of each element will be described next.

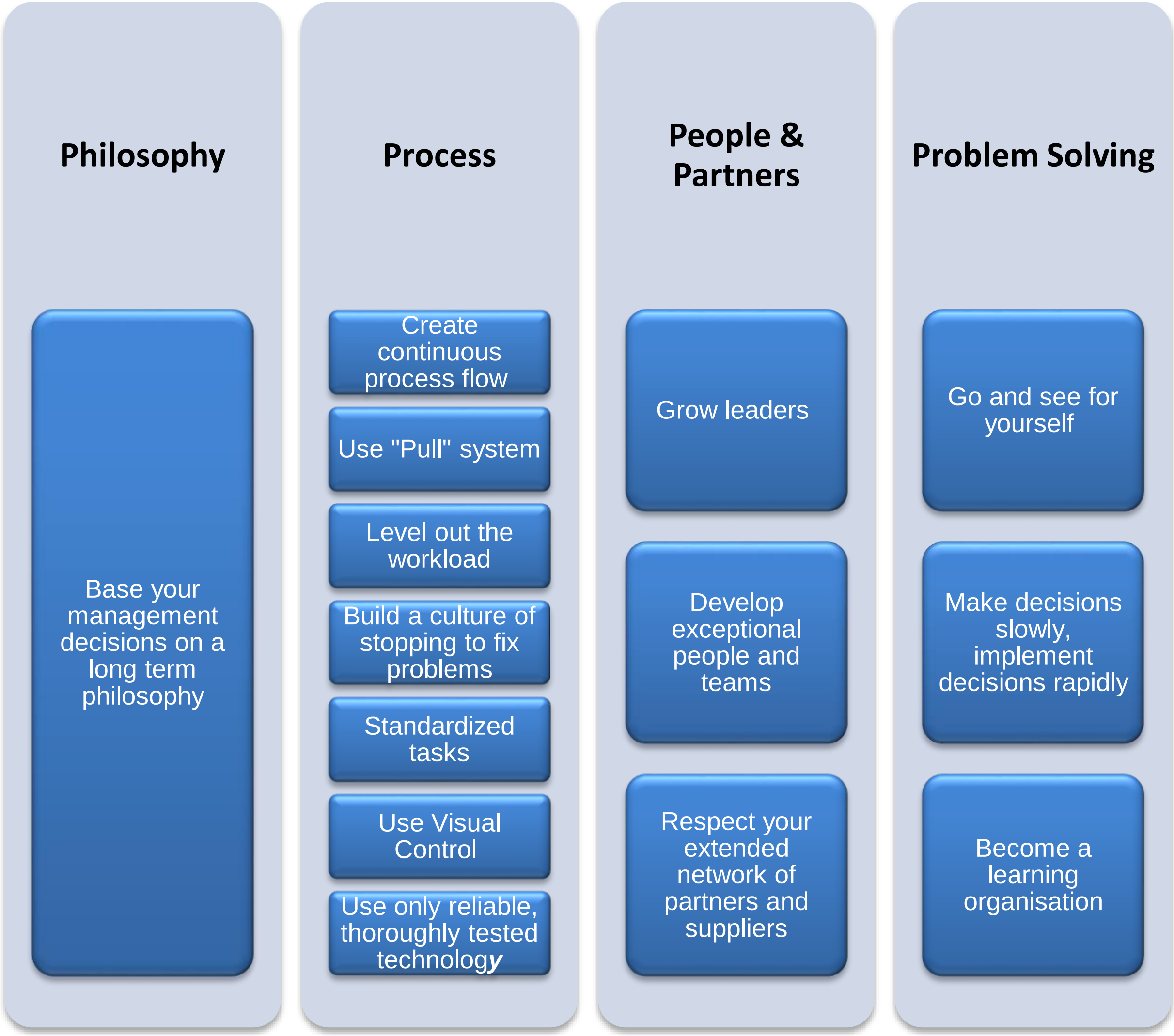

Figure 2.1: 14 Toyota Way Management Principles in the 4P model (Liker, 2004)

Philosophy – Long term philosophy

The Toyota Way's first principle is that of basing management decisions on a long term philosophy, even at the expense of short-term financial goals. In describing this principle, Panneman (2016) describes that the mission of a company should consider contribution to growth of the economy, wellbeing of employee and growth of company as opposed to financial goals.

Process – The right process will produce the right results

Under process, Liker considers the principles that look at the technical side of Lean Manufacturing and describes tools that facilitate a Lean outcome (Liker, 2004). In the summary by Panneman (2016) he highlights that this is where most companies focus on when it comes to Lean implementations and if the other three principles (3P's) are neglected, probability of a failed implementation is higher. This sentiment is echoed by Slack & Michael (2011) who highlight that some organisations see the Lean approach as consisting almost exclusively of the tools that support waste elimination. This approach falls short as without behavioural change, sustained and effective waste elimination is hindered.

People and Partners – Add value to the organization by developing your people

Sustainable long term growth requires that you invest in your people and partners (Panneman, 2016) as people are the ones that make the tools described in Process above work. TPS advocates for growing leaders who understand the work, live the philosophy and teach it to others so that principles are ingrained (Liker, 2004). This principle is important to ensure continuity and transfer of skills among the workforce. Toyota is known to treat suppliers like they treat employees by challenging them to do better and helping them to achieve it and this is the eleventh principle.

Problem Solving – Continuously solving root problems drives organisational learning

TPS advocates for a learning organisation through relentless reflection (Hansei) and continuous improvement (Kaizen) (Loow, 2015). This learning happens at the work place where the problems occur as opposed to the office and so TPS promotes that people strive to get a better understanding of the situation by seeing the problem themselves (Panneman, 2016).

2.2.3 The Five Lean Principles

The origins of the word 'Lean' in relation to the manufacturing industry was first used by Womack, et al. (1990) when they used the term Lean production to contrast Toyota with the Western 'mass production' developed by Henry

Ford. This is documented in the book, “The Machine that Changed the World” and from there, the term Lean Manufacturing was birthed (Bicheno & Holweg, 2009).

Womack & Jones (2003) have described Lean in five principles and they extended the application beyond manufacturing. They consider the application of Lean in an enterprise in other industries in addition to manufacturing. The five principles display a journey of Continuous Improvement as opposed to a sequential, once off procedure as such they are represented in a cycle in Figure 2.2 and elaborated below. This principle is key in understanding Lean implementations as some have taken a once-off approach and the results have not been sustained in the long term.

Figure 2.2: The Five Lean Principles (Lean Enterprise Institute, 2016)

1. Identify value – specify what creates value from the customer’s perspective
2. Map the Value Stream – identify all steps across the whole value stream
3. Create Flow – make those actions that create value flow
4. Establish Pull – only make that which is pulled by the customer just-in-time
5. Seek Perfection – strive for perfection by continually removing successive layers of waste

2.2.4 Choosing a Lean Framework

With masses of literature describing Lean, consolidating it into a framework has been a challenge (Lyons, et al., 2011). While the principles of the Toyota Production System and the Five Lean principles described earlier are the foundation of Lean, the concept has evolved further through application. Framework development is further complicated as there is confusion on what can be regarded as Lean and what cannot. To add to the complexity is that there are numerous terms describing different aspects of Lean such as Toyota Production System, Six Sigma, Just-In-Time, Lean Production and Theory of Constraints among others. According to Lyons, et al. (2011), several authors have attempted to combine the different elements of Lean into frameworks but there has not been unanimous agreement on a particular framework and as such, many frameworks exist. In their research, Lyons, et al. (2011) sought to determine the extent to which Lean thinking can be employed as an appropriate manufacturing philosophy in process industries and explore the suitability of the underlying principles that drive the implementation of Lean. They sought from literature broadly independent dimensions of Lean that are both contemporary and conspicuous in literature and classified them under four main Lean principles. The authors did an expansive detailed search of literature to identify key references associated with each of these principles. They had between 14 and 20 references for each principle to try and gather as much detail on the tools and practices that support the Lean principle.

These four principles are (Lyons, et al., 2011):

1. Alignment of production with demand
2. Elimination of waste
3. Integration of suppliers
4. Creative involvement of the workforce

The four principles chosen by the authors are consistent with Slack & Michael (2011) who defined the four elements of Lean to be waste elimination, involvement behaviour, customer focus and synchronisation. Both sources highlight that while the four principles are distinct, they are mutually supportive and when they mesh together they form the Lean approach (Slack & Michael, 2011), (Lyons, et al., 2011). Focusing on the customer results in aligning production with demand and for this to happen, integration of suppliers so that goods and spares flow in a synchronised manner is required. In each of these steps there are opportunities to eliminate waste and enhance alignment of production with demand. Involvement of the workforce will drive continuous improvement in all these principles. High workforce engagement leads to improved productivity.

While this framework is not exhaustive, the extensive research done by Lyons, et al. (2011) to consolidate the most authoritative Lean research has resulted in a solid Lean architecture that is coherent and uncomplicated with depth. Furthermore, the authors' intention for this framework was that it be used as a representative Lean model that can be utilised in a practical manner for determining the adoption of Lean thinking and principles. In their research, the authors went on to use this framework to evaluate Lean implementations in various processing industries and then compare them to discrete manufacturing industries where Lean principles originated (Lyons, et al., 2011). A similar approach was subsequently followed by Loow (2015) when he used this framework to evaluate around 17 various Lean implementations done in mining contexts specifically and to identify which Lean tools were relevant to a mining context. This framework is appropriate as there are some similarities between the process industry and the mining industry. There are some activities that are intermittent and in batch while others are continuous as identified by Lyons, et al. (2011) when they classified process industries and evaluated the adoption of Lean using the framework. This methodology can be extended to mining.

Figure 2.3 shows that the framework proposed by Lyons, et al. (2011) starts with defining the ultimate Lean goal of reducing cost, increasing productivity and improving quality to increase customer value and profit. This is consistent with Slack & Michael (2011) who describe the aim of the Lean approach as being able to meet the demand instantaneously, with perfect quality and no waste. The Lean Enterprise Institute (2016) have a similar understanding of Lean as maximising customer value while minimizing waste. The four broad principles defined by Lyons, et al. (2011) contribute in an interlinked way to achieving the Lean goals. Each of the four principles has certain tools and practices that are used to achieve the principle and will be elaborated on next. In this elaboration, the connection of the framework to the Lean foundation principles described by TPS and the five Lean principles will be highlighted as well.

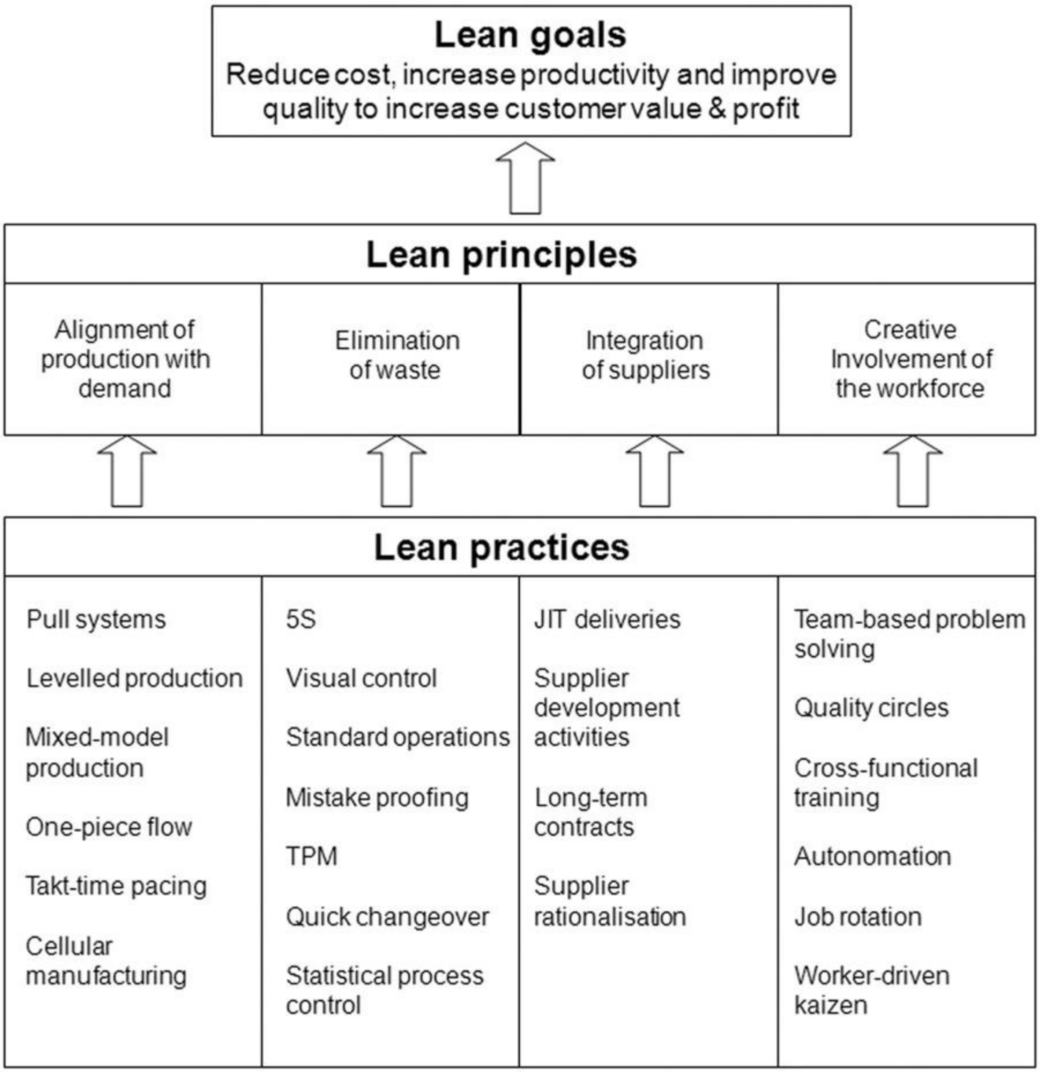

Figure 2.3: Outline of Lean thinking framework proposed by Lyons (2011)

Alignment of production with demand

This involves producing at the pace of customer demand and facilitating flow through the systematic elimination of non-value adding activities (Lyons, et al., 2011). This is to be achieved at the right quality specified by the customer. The most common approach to achieving customer-based triggering is by utilising ‘pull’ control as opposed to push control (Slack & Michael, 2011) and this is identified as one of the tools in Figure 2.3. In Womack & Jones (2003), this is described under the third and fourth Lean principles of creating flow and establishing pull where you only make that which is pulled customer just-in-time. Other practices identified in Figure 2.3 are levelled production, mixed-model production, one-piece flow, takt-time pacing and cellular manufacturing. These tools are consistent with the following Toyota Management Way principles covered under the 4P principle of Process (Liker, 2004):

- Using a “pull” system to avoid overproduction (Kanban)
- Levelling the work load to prevent waste (Heijunka)

Elimination of waste

There is unanimous agreement amongst researchers and practitioners that waste elimination is an integral part of Lean according to Lyons, et al. (2011) who cite 21 other sources that support this notion. Waste is broadly defined as any activity that does not add value (Slack & Michael, 2011). Identifying waste is the first step towards eliminating it and the seven types of wastes identified by Ohno from the Toyota Production System are at the core of this principle (Bicheno & Holweg, 2009).

Other activities that can be used to identify waste include the first two Lean principles from Womack & Jones (2003) on identifying value and mapping the value stream. From this process you can determine which activities are value adding and non-value adding. To eliminate waste, various tools can be used depending on the waste being eliminated. These tools are shown on the Lean Framework in Figure 2.3 under the principle of elimination of waste and they include visual control, 5S, standard operations, mistake proofing, TPM, statistical process control among others. These tools are consistent with the following Toyota Management Way principles covered under the 4P principle of Process (Liker, 2004):

- Elimination of waste (7 types of waste)

- Standardised task and processes are the foundation for continuous improvement (Kaizen) and employee empowerment
- Use visual control so no problems are hidden (includes 5S)

Integration of suppliers

The principle of aligning production with demand requires a close relationship with suppliers as they must deliver parts and materials at the right quality to match customer demand (Lyons, et al., 2011). Slack & Michael (2011) refer to this as synchronised flow where items in a process flow smoothly with an even velocity throughout. Practises included in this principle include JIT deliveries, supplier development activities, long term contracts and supplier rationalisation. These tools are consistent with the following Toyota Management Way principle covered under the 4P principle of People and Partners (Liker, 2004):

- Respect your extended network of partners and suppliers by challenging them and helping them improve

Creative involvement of workforce

Instilling a culture of process improvement activities into the minds of the workforce known as 'soikufu' in Japanese manufacturing is essential for elimination of waste (Lyons, et al., 2011) and this has been emphasised throughout this section. This approach is reiterated by 19 other sources researched by Lyons, et al. who mention the importance of a vitalised workforce, employee participation, team problem solving, worker empowerment through training among other things. Slack & Michael (2011) suggest that the smooth flow that comes with alignment of production with demand motivates individuals to help their colleagues. They work together to improve the whole process rather than focusing exclusively on their own area of direct responsibility. This drives involvement behaviour which in turn leads to innovation in waste elimination.

Practices that contribute to achieving this principle include team based problem solving, quality circles, cross functional training, autonomation, job rotation, worker-driven kaizen. These tools are consistent with the following

Toyota Management Way principles covered under the 4P principles of Problem solving and People and Partners; (Liker, 2004):

- Grow leaders who thoroughly understand the work, live the philosophy and teach it to others
- Develop exceptional people and teams who follow your company's philosophy
- Go and see for yourself to thoroughly understand the situation (Genchi Genbutsu)
- Make decisions slowly by consensus, thoroughly considering all options; implement decisions quickly
- Become a learning organisation through relentless reflection (Hansei) and continuous improvement (Kaizen)

In Womack & Jones (2003) they refer to this in the fifth principle of seeking perfection where an organisation strives for perfection by continually removing successive layers of waste.

2.3 Implementation of Lean in mining

Various authors have come to the same conclusion that current market conditions have forced mining companies to look to Lean principles that have resulted in a step change in performance in manufacturing with the hope that they bring the same result to their operations. One author suggests that because minerals are sold into a commodity market over which miners have little control; effective and efficient operations will define a mine's competitive edge (Hattingh & Keys, 2010). As such, an increased focus on operational performance is necessary. Another author points to the uncertainty that remains in the global economy and the pressure on costs and profitability that is affecting mining company profits (Dassault Systemes, 2015). This sentiment is shared by (Sanda, et al., 2011) who affirm that the Lean principle of eliminating waste will lead to reduced costs.

Lyons, et al. (2011) define the objective of Lean as; "to reduce cost, increase productivity and improve quality to increase customer value and profit". Literature on Lean implementations in mining point to the same drivers. The objective of reducing cost and increasing value in mining operations is highlighted by Nadeau, et al. (2015) and Sanda, et al. (2011). Increased productivity as a goal of Lean implementation is cited by Dassault Systemes (2015) and Hattingh & Keys (2010). Profitability is discussed by Dassault Systemes (2015) and Deloitte (2016).

A comprehensive study on existing literature on case studies and conceptual studies related to mining Lean implementations was done by Loow (2015). In this study the author considers which Lean tools were best implemented as well as benefits, success factors and challenges experienced during implementation. In a research report by Nyamarebvu (2012), 42 South African mining companies were surveyed to establish which Business Improvement tools they had implemented. A detailed discussion on the appropriate tools that can be implemented in a mining context will follow in section 2.4.

2.3.1 Benefits of Lean implementation

The extent to which success has been reported is hard to comment on as they are few case studies in literature to date. Table 2.1 illustrates some of the case studies available. No negative results have been reported to date though there are occurrences of neutral ones (Loow, 2015). The major themes coming out point to increased productivity, improved stability and increase in work force contribution and problem solving.

While mining literature maybe limited, these benefits are consistent with findings from the wider context. In literature reviewed by Basin & Burcher (2006) on benefits realised in manufacturing, they cite that there are studies that provide empirical evidence of productivity gains and the positive impact on competitiveness. These themes are elaborated below:

Increased productivity

One of the biggest benefits that is reported by various authors is that of increased productivity. Castillo, et al (2014) observe an increase in mined tonnage per miner and increased length of tunnelling development per day. Dassault Systemes (2015) and Loow (2015) also talk about increased productivity and relate it to throughput increase. Hattingh & Keys, (2010) refer to increased productivity at the Rio Tinto mining operations which is reiterated by Dunstan, et al. (2006). In the study done by Nyamarebvu (2012) where 42 South African companies were analysed, he found that the Lean implementations resulted in production improvements of between 5 – 10% with some large companies realising an improvement of up to 20%.

Improved stability

Another benefit is that of improved stability that has a positive domino effect on other benefits. According to Dassault Systems, Lean practices result in operational stability that leads to increased throughput. Further benefits include reduced waste and associated costs and predictable production and quality performance (Dassault Systemes, 2015). Implementation at Rio Tinto Aluminium is reported to have resulted in stability as there was more control, ability to identify issues and implement pre-emptive measures (Dunstan, et al., 2006).

Increased workforce contributions

Other benefits reported are how the Lean implementations at Weipa Mine and PT Inco Sulawesi Island mine resulted in significant workforce contributions and problem solving that led to efficiency gains (Alexander Proudfoot, 2009). Work was done to establish the benefits of Lean in construction for mining development projects. It was found that the Lean principles resulted in improved planning and coordination, reduced waste and consolidated work teams among other benefits (Castillo, et al., 2014).

Several authors reiterate that they found the benefits to be short term (Castillo, et al., 2014), (Hattingh & Keys, 2010) and (Loow, 2015). As a result there is a need to explore how these benefits can be sustained and be enjoyed over the long term.

2.3.2 Challenges when implementing Lean

In evaluating the challenges reported from Lean implementations, it becomes important to discuss the factors that are unique to a mining environment that complicate Lean implementations. Where manufacturing has a consistent production line, mining comes with inherent variation (Loow, 2015). Mining comes with uncertainties and numerous sources of significant variability and these need to be considered when designing mining Lean implementations (Nadeau, et al., 2015). These differences have been summarised by (Dunstan, et al., 2006) where he compares the mineral business to the automotive business The two main sources of inherent variation are that of the environment itself due to the nature of mining which is spread out across a geographical space and the raw materials that are processed from this environment. These differences affected which tools could be used and this is a major consideration in planning future Lean implementations. This will be evaluated further in section 2.4 when determining the most appropriate Lean tools for a mining environment.

2.3.3 Key success factors in mining Lean implementations

Analysing the success factors for a Lean implementation is fundamental to unlocking the long term sustainability that was found to be lacking in section 2.3.1 when the Lean benefits were reviewed. This aspect has been well documented in previous literature and it will be analysed under three key themes that are emerging namely; senior management leadership, workforce buy-in and training and experience.

Senior Management Leadership

The importance of having senior management support is highlighted across literature. Linked strongly to this is aligning initiatives to business KPIs that are tracked and part of the portfolio as evidenced at the three operations analysed by Hattingh & Keys (2010). This is supported by Dassault Systemes (2015) who advise that the Lean implementations need to be visible to all levels of leadership from executives to management including the front line managers. This visibility is expressed when managers step up to play the role of mentors who can champion the removal of barriers to the change and demonstrate their commitment to the implementation (Nadeau, et al., 2015). Similar sentiments are echoed by (Dunstan, et al., 2006), (Loow, 2015) and (Nyamarebvu, 2012).

While mining case studies are limited, a study of critical success factors for Lean implementations in the broader context show that there is general agreement that the most important factor in implementation is top management support and enthusiasm (Coronado & Antony, 2002). This is repeatedly highlighted by more than eight authors who are analysed by Kundu & Manohar (2012) in their study on critical success factors in the manufacturing industry. The authors describe this theme as having active leadership; evidence of management commitment and involvement; top management support (including financial support) and many others.

Workforce buy-in

Another theme that contributes to successful Lean implementation is that of getting buy-in from the workforce at large. From the survey responses received by Nyamarebvu (2012), teamwork and synergy were found to be an enabling factor across all operations. Part of getting this buy-in could include engaging workplace leaders and empowering them to set standards for their teams (Dunstan, et al., 2006). Another option that is emerging could be to identify change agents that can drive the buy-in from within (Jon, et al., 2000). In doing this you draw on local knowledge and expertise which is a crucial component of succeeding.

Broader literature analysis by Kundu & Manohar (2012) reveal that this theme is key even in the wider context of Lean implementations. This is backed up by several other authors who talk of building organisational culture; employee autonomy to make decisions and team work among others.

Training and experience

Training and experience has repeatedly been identified as a success factor to Lean implementations. This comes out in different forms as there is training to equip the workforce as well as importing experience to guide and facilitate the implementation. Hattingh and Keys (2010) describe both; they recognise that successful implementations have come with a high training investment and have also required previously experienced facilitators and coaches such as Industrial Engineers. From the training, there is a structured process that can be followed for root cause and problem solving. In addition, they highlight that this knowledge gain and problem-solving ability need to be transferred to all levels of the business to ensure sustainability. The sentiments of previous experience contributing to success are shared by Loow (2015) and Dunstan, et al. (2006). Nyamarebvu (2012) writes of embedding a culture of innovation and this comes through training and experience.

Similar to the theme of Senior Management Leadership, there is extensive evidence in the broader Lean context of training and experience being a critical success factor for Lean implementations. In the literature review by Kundu & Manohar (2012), they identified at least four authors who talk of aspects like skills and expertise; sound professional training in tools, education and training as key success factors in any Lean implementation.

The lack of experience and requirement for training is consistent given that Lean principles have been adopted from manufacturing and are fairly new to mining. There is need to develop the experience required to sustain the implementation and enjoy long term benefits. There is a case to build experience and this can be done by building Lean competency in employees. This could result in more sustainable benefits from Lean implementations. Section 2.4 to 2.6 consider an approach to building competency in a mining workforce. Firstly, given the challenges of the mining environment itself, the right tools need to be identified from the onset. The next step will be to evaluate the success factors against a change management tool and thereafter consider alternative ways of building the Lean competency.

Other factors

These factors were not as recurring in literature as the three highlighted above but came out in various sources nonetheless. These are summarised below:

- Access to operational data for statistical process control (Dassault Systemes, 2015); Visual representation of key data (Dunstan, et al., 2006)
- Enabling technology (Dassault Systemes, 2015)
- Companies focused on value creation not cost reduction (Nyamarebvu, 2012)

2.4 Basic Lean tools for introducing Business Improvement skills in mining

While there is a full suite of Lean practices that are presented in the framework proposed by Lyons, et al (2011); Loow (2015), considers which Lean tools and practices are relevant to mining companies. There are some case studies, albeit few, which provide context on the basic Lean tools that the mining workforce need to be trained on through the Learning factory. In evaluating the existing case studies, Table 2.1 was compiled to classify the Lean practices that had been implemented at other mining operations using the Lean framework defined by Lyons, et al. (2011).

Table 2.1: Summary of Lean principles implemented at different mining operations

	Lean principles implemented			
Operation	**Elimination of waste**	**Align production with demand**	**Integration of suppliers**	**Creative involvement of workforce**
AngloAmerican Thermal Coal (Hattingh & Keys, 2010)	Asset optimisation			
Pt Inco (Alexander Proudfoot, 2009)				Employee engagement
Weipa Mine Queensland (Dunstan, et al., 2006)				Problem solving at workforce level
Chelopech Mine (Hattingh & Keys, 2010)	-Work study -Theory of Constraints -DMAIC (Six Sigma)			CI Framework/ Culture
Rio Tinto Alumina (Dunstan, et al., 2006)	-CI Tools -Six Sigma			
Operation name not specified - Case Study by	-Optimised scheduling / planning			

Dassault (Dassault Systemes, 2015)	-Statistical Process Control			
Bauxite Mine (Dunstan, et al., 2006)	-Visual Control + 5S -Standard work			-Learning program -Improved problem solving
Swedish underground mine (Sanda, et al., 2011)	MME Reliability Operations & maintenance procedures	Continuous production		

The principle that is most applied is that of elimination of waste according to the summary in Table 2.1 with different practices of waste elimination being adopted at the various operations. Loow (2015) came to a similar conclusion in his analysis and in explaining this finding he found that the Lean practices in waste elimination are not constrained by the mining environment. Dunstan, et al. (2006) refer to the Lean Temple that describes a complete Lean system structure that was introduced to Rio Tinto mining operations. The Lean Temple is illustrated in Figure 2.4 and it has foundation elements that form the base of a Lean system and should be implemented first. All the foundation elements fall under the Lean principle of Elimination of Waste.

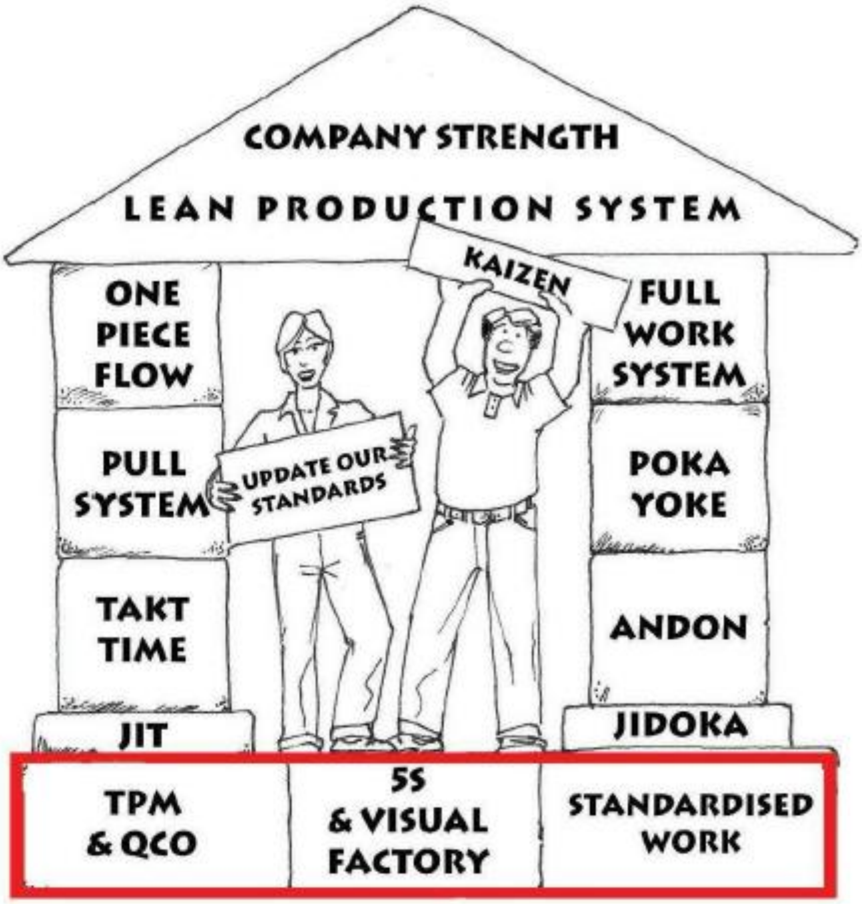

Figure 2.4: The Lean Temple (Dunstan, et al., 2006)

The next widely applied principle is that of creative involvement of the work force with the practices of team-based problem solving and continuous improvement being the most commonly applied. Loow (2015) highlights that the mining environment could make it difficult to facilitate workforce gatherings as the distance to workplaces in some operations is long as is the case with underground mines.

Table 2.1 shows that the principles of aligning production with demand have been implemented to a much lesser extent. No evidence of implementation of integration of suppliers is given in case studies considered. Loow (2015) argues that the integration of suppliers is relevant to the support structures like supply chain management and not the mining environment directly. Nadeau, et al. (2015) differ with this view point as they consider the option of optimising the logistics chain using Six Sigma for example. According to Loow (2015), the mining environment itself is a barrier to aligning production with demand and this has resulted in very limited applications of this principle. This sentiment is also shared by Dunstan, et al. who presents the differences characteristic to mining that affect Lean implementation. In the mineral business some operating units such as smelters or refineries cannot be stopped so there is inherent productive push in the process.

Conceptual studies on relevant Lean practices that can be employed in the mining environment have also been conducted (Loow, 2015); (Yingling, et al., 2000) in addition to the practical case studies. The conceptual studies show more adaptation possibilities compared to the few practices that are demonstrated in case studies. Yingling, et al. (2000) makes a case for aligning production with demand by focusing on matching product quality to customer demand but as described earlier in this section, there is no evidence in case studies to support this.

Based on the literature presented, the author has consolidated the main Lean principles relevant to a mining environment. These principles can be introduced by a mining company that wants to impart Lean principles to develop Business Improvement Skills to their workforce. From Table 2.1, the most widely applied principles are those of Waste Elimination and Creative Involvement of the workforce and practices in these principles will provide a starting point. This approach is similar to the approach by Rio Tinto where they chose to introduce foundation Lean elements first and then build upon that base as shown on the Lean Temple in Figure 2.4 (Dunstan, et al., 2006).

2.5 Change management in Lean implementation

Lean methods have been identified as a key that could unlock value in the same way they did for manufacturing and other enterprises. There are some critical success factors that result in the value being unlocked and the three main factors identified are senior management leadership, workforce buy-in and training and experience. All these present significant changes for the operation that embarks on a Lean transformation journey and change in organisations needs to be delicately handled. This is not limited to mining organisations as similar challenges have been reported with other change initiative in other industries. In a report by McKinsey, they found that only one third of all transformations are successful and unfold their full impact (McKinsey, 2016). They found that the remaining 64% of programs fail because there are gaps in specific skills that employees need to tackle transformative tasks. The study also found that there is lack of will to make change happen.

In the mining industry specifically, there has been significant technical and workforce reorganisation over the last twenty years in shared services, integration of suppliers, automation, digitization, scale of equipment, Continuous Improvement and Lean Six Sigma with mixed results (Bekhet & Zauszniewski, 2012). In this study they found that only one in ten companies actually sustains improvements beyond four years.

Work done by Kamau (2013) on understanding the status of Lean manufacturing in the Kenyan manufacturing sector showed that the implementation of Lean management requires change management skills. These sentiments are further echoed by Grovom (2013) who found that in Lean implementation, there is a need to understand the extent to which the culture change. To do this, change management models need to be considered.

2.5.1 Change management models

Several theories of change management exist. Change management models can assist in the development of a cultural transition program. Some change management models that are available include (Kamau, 2013):

- Kurt Lewin three phases of change theory of unfreeze, change and refreeze
- McKinsey 7-S framework
- ADKAR model
- Kotter’s eight-step model
- EASIER approach by D.E. Hassey

These models have been applied to understand different Lean implementations. Kamau (2013) used Kotter's eight-step model to look at the status of Lean manufacturing in the Kenyan manufacturing sector. Grovom (2013) looked at the sustainable Lean 5S implementation using the ADKAR model.

In a study by Calder (2013), they compare various change management models and find that there is overlap in the steps proposed by the different models and it comes down to requirements of the organisation. They assert that where change with individuals across all levels of an organisation is concerned, the ADKAR model is more applicable. The ADKAR model was developed by Jeff Hiatt of Prosci Research in 1998 to determine if change management activities were having desired results during organisational changes (Educational Business Articles, 2016). This same approach will be used to evaluate the Lean implementation success factors in mining described in section 2.3 as these factors are across different individuals in an organisation. The ADKAR model will be described first followed by the evaluation of Lean implementation success factors.

2.5.2 ADKAR change management model

Prosci describe the ADKAR model as a goal-orientated change management model to guide individual and organizational change (Prosci, 2016). It is a five step model that can be used to manage change on the individual and organisational level. ADKAR is an acronym for Awareness, Desire, Knowledge, Ability, Reinforcement and these are the milestones that an individual must achieve for change to be successful. The ADKAR model recognises that change happens at an individual level first in order for a group or organisation to change. It provides a framework that allows a leadership team and change management team to focus on activities that that will drive individual change and therefore allow organisational results (Prosci, 2016). The five steps of ADKAR are cumulative and progress in order. These are described in Figure 2.5.

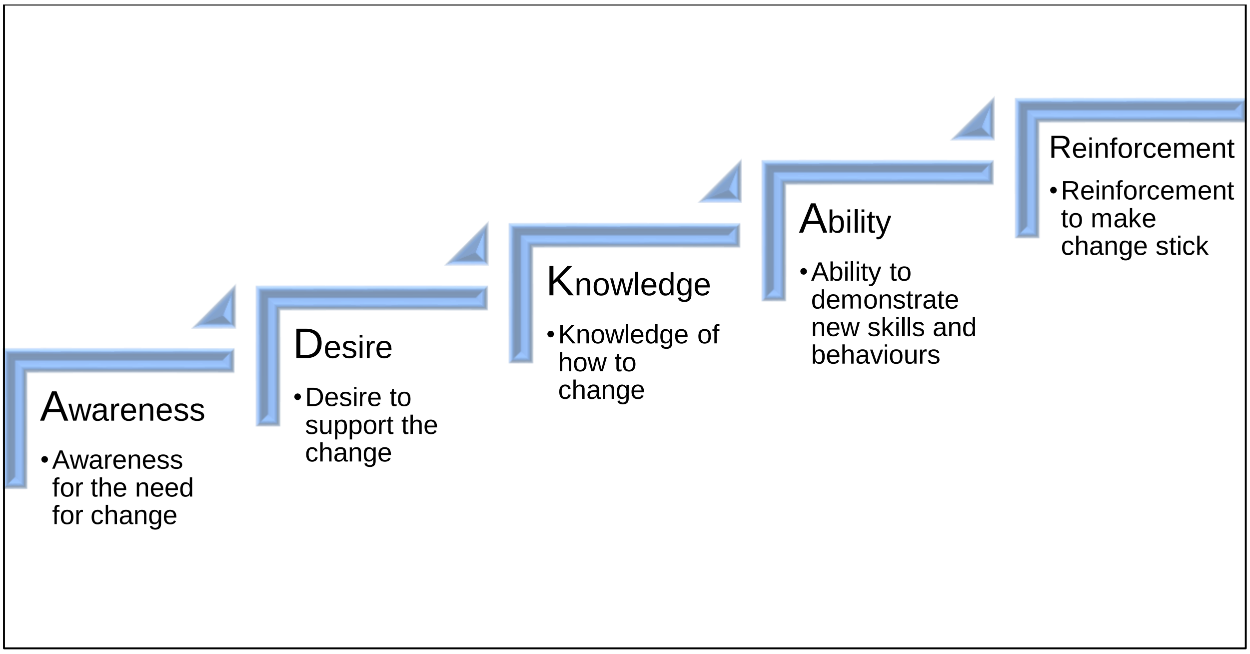

Figure 2.5: Five steps of ADKAR (Prosci, 2016)

Since ADKAR is a process for managing change for an organisation as a whole and on an individual level, Prosci describe what each of the five steps mean to each entity and these are tabulated in Table 2.2.

Table 2.2: ADKAR - organisation and people side of change

Step	Organisation side of change	Individual side of change
Awareness	Of business reasons for change Outcome of early communications related to an organizational change	Of the need for change
Desire	To engage and participate in the change Outcome of sponsorship and resistance management	To participate and support the change
Knowledge	About how to change Outcome of training and coaching	Of how to change and what change looks like
Ability	To realise or implement the change at the required performance level Outcome of additional coaching, practice and time	To implement change on a day-to-day basis
Reinforcement	To ensure change sticks Outcome of adoption measurement	To keep the change in place

2.5.3 Relationship between success factors for implementing Lean in mining and ADKAR

As mentioned earlier, ADKAR was initially developed as a tool to determine effectiveness of certain change management activities in achieving desired organisational change results (Educational Business Articles, 2016), (Prosci, 2016). Earlier in this Literature Review, the success factors for implementing Lean in mining were described in section 2.3.3. Next step is evaluating these success factors against the ADKAR model to determine what initiatives in change management can further promote successful mining Lean implementation. The three main success factors distilled from literature are:

1. Leadership buy-in
2. Previous experience and training
3. Workforce buy-in

A relationship between the success factors and the supporting steps in the change management process has been identified as part of this research. This is illustrated in Figure 2.6. Inside the bubbles are the themes that are emerging as success factors for Lean implementations to succeed in mining.

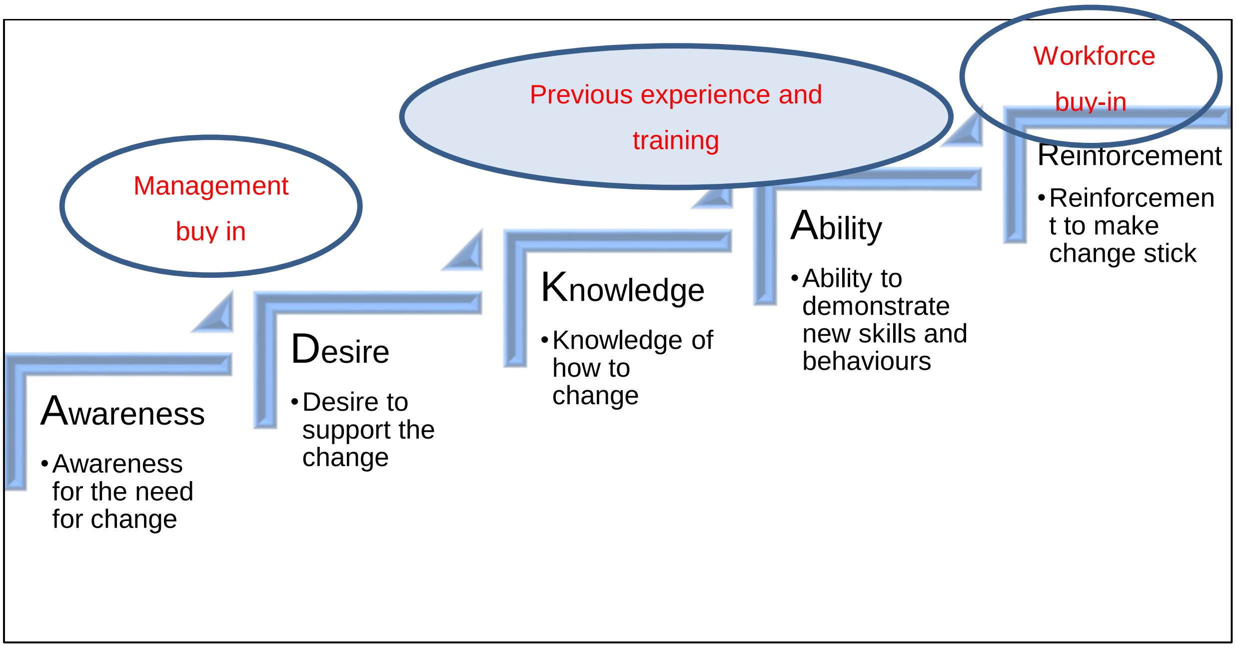

Figure 2.6: Mapping success factors for mining Lean implementations onto ADKAR

According to ADKAR, the first step towards change is awareness for the need for change and to achieve that, the business reasons for change need to be communicated. From Table 2.2, this awareness is the outcome of early communications about the organizational change. Following awareness, the next step is to create desire to participate and engage in the change. This can be achieved by sponsorship and resistance management. The steps to getting the awareness and desire for the change would require that management first defines and articulates the reasons for themselves and when they have the reasons they can then communicate them to the rest of the workforce and create the awareness and desire at the subsequent levels in the workforce. This is consistent with getting management buy-in that could lead to successful implementation. This management support would also start to generate workforce support from a top-down approach. Figure 2.6 shows the management buy-in success factor bubble hanging over the awareness and desire steps to illustrate this relationship.

Knowledge of how to change and ability to implement change are the next two steps in ADKAR after awareness and desire. Similar elements contribute to achieving these steps namely training, coaching as well as practice over time. Experience and training was identified as one of the top success factors for Lean implementation and this requirement comes with training, coaching and expertise in order to build competency.

Last step in ADKAR is reinforcement in order for the change to stick. This is an outcome of measuring how well the change has been adopted, developing corrective actions where there are shortfalls and being able to recognise successful change. Workforce buy-in is crucial at this stage as they embrace the change and need to support the change for the Lean principles to embed.

All the factors that drive a successful Lean implementation are important and are interrelated just as the steps of ADKAR are sequential and are all important in successfully changing and sustaining the change. There is room to explore deeply how to achieve all three main success factors in order for a Lean implementation to be successful. This study will focus on the aspect of knowledge and training which speaks to knowledge about the change and ability to implement the change on the ADKAR model. This lack of knowledge and ability is evident because Lean concepts are fairly new to mining and are not widely applied yet. As such there is a case to build experience and this can be done by building Lean competency in employees. This is one aspect that will contribute to more sustainable benefits from Lean implementations for the mining industry.

An approach to building competency will be explored next.

2.6 Learning factories

Given the potential improvements mining companies can be realise from Lean implementations, there is need to find an effective way of building competency in workforces. In a study by McKinsey, it was established that in most instances the broken link in change transformative innovations done by companies has been lack of capabilities and the absence of a skilled workforce ready to achieve change mission (Benkert & van Dam, 2015). This has been identified as a success factor for Lean implementations and is necessary for instilling knowledge about the change and ability to implement the change in the ADKAR change management model. Learning factories offer a possible solution given their demonstrated success in manufacturing. Manufacturing companies needed to be able to quickly adapt to new market conditions (Abele, et al., 2015) and remain competitive in meeting changing customer requirements (Wagner, et al., 2012). According to Tisch, et al (2013); these changing conditions can be economic, social or technical and a rapid adaptation was necessary. Effective methods for developing employee competencies were required as traditional methods show limited effects (Abele, et al., 2015). Competent employees are a crucial prerequisite for competitive future production and enables fast problem solving and continuous improvement (Tisch, et al., 2013). Given the turmoil that the mining industry finds itself in, the requirement to adapt to change quickly, remain competitive and build competency fast, Learning factories offer a possible alternative.

By definition, a Learning factory refers to a small scale factory which closely mimics a real factory where participants can learn by doing (Abele, et al., 2015). This is elaborated by Jaeger, et al. (2012) who define a learning factory as a system that has elements of both words i.e. a combination of a real learning environment in a real production process. Learning factories provide an environment where participants can learn by doing and this type of learning has been proven to be more effective as it leads to greater retention and greater ability to apply the learnings (Cachay, et al., 2012).

2.6.1 How Learning factories work

It is said that Learning factories promote the development of participants' ability to master complex unfamiliar situations (Abele, et al., 2015). This is a key motivation for the use of Learning Factories as the concepts of Lean are unfamiliar to the majority of mining workforces. Such an environment where the internalisation of these new concepts can be accelerated could promote sustained implementation success. The two elements that drive the effective competency development are that the learning is done in an environment that is close to a real factory environment and that it is hands-on experience for the participants (Abele, et al., 2015).

Learning factories use an action-orientated learning process that focuses on competency development (Cachay, et al., 2012). From the competency model cited by the same source, important to developing a competency is the ability to master knowledge in such a way that there is a cognition and comprehension of knowledge. With the action orientated learning process, self-organising competencies can be developed enabling learners to act independently and be focused as well as performance orientated (Cachay, et al., 2012).

Studies reviewed by Jaeger, et al. (2012) on problem-based and action orientated learning suggest it is possible to increase educational effectiveness and efficiency compared to traditional educational sources. Action orientated learning goes a step further by catering for visual learners through active, visual and tactical teaching methods. This is further supported by the learning pyramid in Figure 2.7 that shows that the recall rate of learners who learn by doing is higher than those who learn by what they hear and see. Two weeks after learning a subject, there is 90% recall of what has been taught by seeing and doing compared to 20% recall of what has been taught by hearing (Jaeger, et al., 2012).

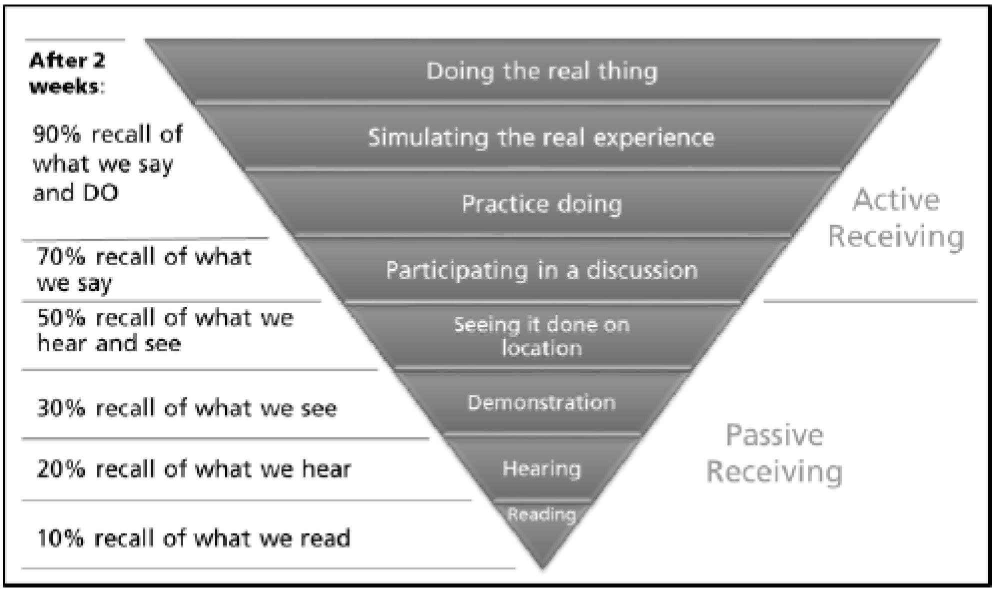

Figure 2.7: Learning pyramid (Jaeger, et al., 2012)

A report by McKinsey agrees with these findings as they say adults learn best in an environment that offers them a rich interactive experience and the freedom to experiment and make mistakes without risk (McKinsey, 2016). In this interactive environment, experiential learning and learning by doing improves recall rates to 80 – 100% as shown in Figure 2.8.

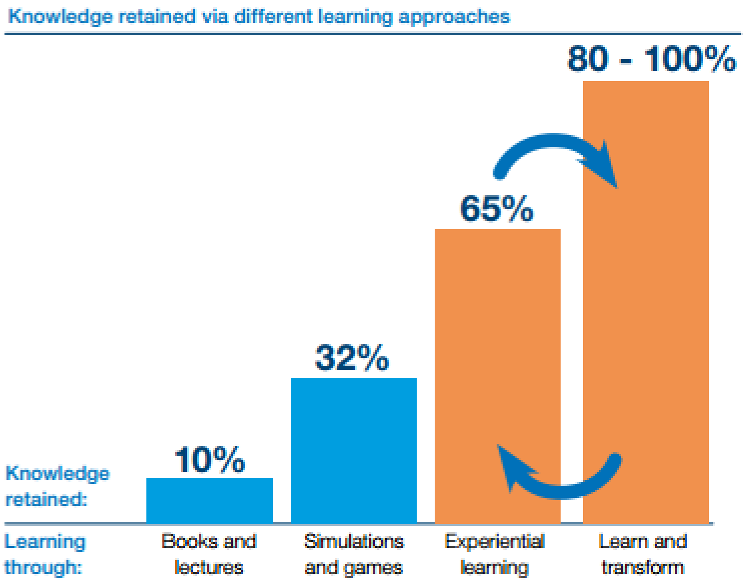

Figure 2.8: Knowledge retained via different learning approaches (McKinsey, 2016)

In a study by Cachay, et al. (2012) to investigate the learning success of engineering students in a Learning Factory, the results showed that students have a greater application-performance and a higher degree of action-substantiating knowledge after being taught in a Learning Factory compared to a conventional lecture. This study was based on the need for effective and enduring development of production- related competencies in universities for manufacturing engineers. It was designed to investigate learning success of engineering students in the Learning factory by determining whether the action-orientated Learning factory approach has advantages over conventional teaching methods. They also review to what extent the Learning factory approach exceeds the conventional. The conventional approach was the lecture driven approach that is science orientated with highly abstract content and methods.

In this study by Cachay, et al., (2012), there were two teams, one trained conventionally and the other through the Learning factory. The teams were randomly composed and the comparison group (treated through conventional methods) and the investigative group (treated through Learning Factory) are virtually identical and sufficiently similar. Both teams were assessed in the same way and at the same intervals as follows:

1. Short preliminary test to check initial knowledge on Lean
2. Learning by conventional and learning factory methods
3. Repeat of preliminary tests
4. Apply learning content in real life problems through Operations Task
5. Short interviews to find out how participants have experienced their respective treatments

The results from this study by Cachay, et al., (2012) showed that the preliminary test completed in step 1 shows all participants have an identical initial understanding. In the second test, the investigative group was able to more than double their score. The investigative group was taught through the Learning factory. A major win was that the investigative group answered the comprehension questions better than comparison group in step 3. When it came to applying learning content in real life problems through the operations task, the investigative group outperformed the comparison group. The investigative group's ability to apply the learning in a systematic way and answer comprehensive questions better showed that they had a greater application-performance and higher degree of action-substantiating knowledge than the comparison group. This verified the hypothesis that the Learning factory is more effective than conventional methods.

2.6.2 Learning Factory case studies

Sustained and significant value add from Lean implementation in manufacturing was realised by companies that were able to develop capability at all hierarchy levels and this facilitated the application of newly acquired skills and competencies (Abele, et al., 2015). Learning factories present a new learning approach for the development of staff competencies. Results showed that the development of competencies of employees from all hierarchical levels makes Learning factories attractive (Cachay, et al., 2012).

Work has been done by various authors to classify learning factories based on application (Abele, et al., 2015), (Wagner, et al., 2012). Ultimately, learning factories share a common goal of competency development but this can be in different contexts. The most prevalent applications are education, training and research and these are described below.

1. **Training** – the case for Learning factories for employee training has been made in section 2.6.1. This research fits in this context and has been elaborated on in detail. As of 2015, there were more than twenty companies that were developing employees from top management to line employees in Learning factory environments (Abele, et al., 2015), (Wagner, et al., 2012).

2. **Education** – according to Abele, et al., (2015) the first Learning Factory was birthed at Penn State University for senior engineering design projects with strong links and interactions with industry. Learning factories allow students to train in realistic manufacturing environments that enhances key competences of future engineers (Wagner, et al., 2012) and this has been found to boost innovation in manufacturing. Further, it bridges the gap between what is taught in the classroom and what students need for real-life work and this prepares them to transfer their skills easily (Wagner, et al., 2012).

3. **Research** – Learning factories in research create an awareness for the problems that arise in professional practice and lay groundwork for alternative action. This allows room for experimentation without risk and creative room for constructive failure (Jaeger, et al., 2012). The Learning factory needs to have a high degree of changeability to fulfil this need (Wagner, et al., 2012). The new solutions created can then be transferred to industry. It is worth noting that no Learning Factories in a mining context were identified during this study.

2.7 Evaluating the effectiveness of training in a Learning Factory

In the previous section, a case has been made for using Learning Factories to train mining employees on Lean principles. The next step will be to determine how the effectiveness of training will be measured in the Learning Factory. According to Farjad (2012) and Mollahoseini & Farjad (2012)), training effectiveness is a measure of how well training achieves its intended outcomes. For organisations training employees, it needs to transfer in some way into performance (Broad & Newstrom, 1992). This means that the skills and knowledge learnt during training should be transferred to the job.

One of the most widely used models for evaluation of training effectiveness is the Kirkpatrick Model developed in 1952 (Kirkpatrick & Kirkpatrick, 2006). In a study by Mollahoseini & Farjad (2012) they conclude that while newer models have been developed since 1952, the Kirkpatrick four-level model of training evaluation remains the most popular. This is also confirmed by Bates (2004) and Farjad (2012). According to Kirkpatrick (1998), the process of evaluation is a series of four levels which are evaluated in the order of reaction, learning, behaviours and results. These are defined further in Figure 2.9.

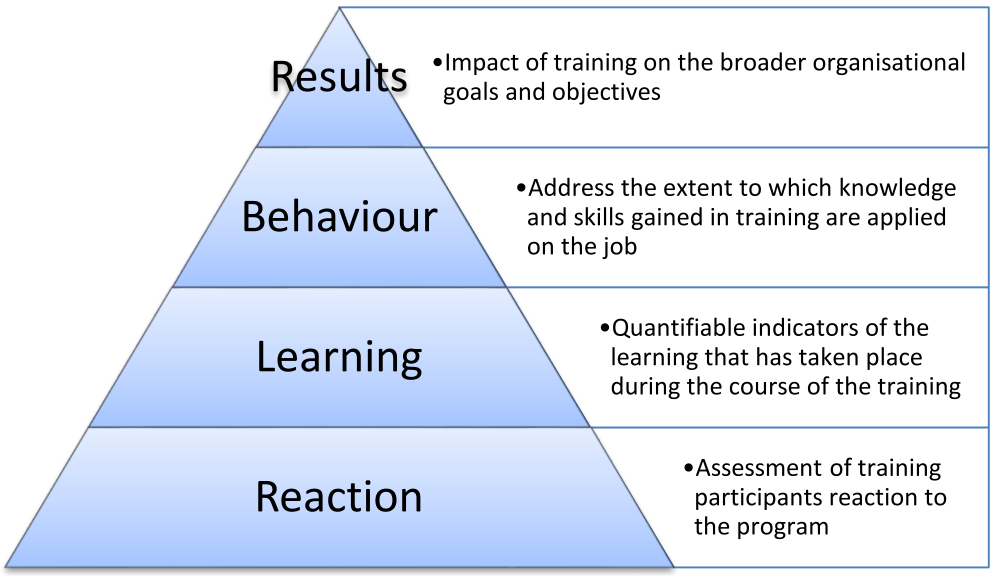

Figure 2.9: Kirkpatrick Model for evaluating training effectiveness (Bates, 2004), (Farjad, 2012), (Mollahoseini & Farjad, 2012)

2.7.1 The Kirkpatrick Model

Each of the four levels will now be elaborated on

Level 1: Reaction

The first level of evaluation is measuring reaction which consists of measuring how participants feel and their perception of the program. According to Kirkpatrick (1996), this will provide information on how well a program was accepted and will be recommended in the future. Further, favourable reactions set up a platform in which participants can be more open to learning which is measured in the next level.

Level 2: Learning

The second level is about determining objectively the amount of learning that took place. Learning is a measure of what principles, facts and techniques were understood and absorbed by the trainees (Kirkpatrick, 1996). In measuring learning, one seeks to understand the measure of knowledge acquired, skills improved or attitudes changed due to training (Kirkpatrick, 1996).

Kirkpatrick (1996) also suggests that when measuring learning of principles and facts a paper and pencil test can be used. Standardised tests or customised tests can be used.

Level 3: Behaviour

Kirkpatrick (1996) recognises that there is a transition between learning and changes of behaviour on the job which is also referred to as transfer or training. Measuring behaviour is more difficult than measuring reaction and learning as many factors can contribute to behaviour. Systematic appraisal of performance before and after training is recommended by Kirkpatrick (1996). While Farjad (2012) suggests looking at improved results or performance in the immediate place or line of work.

Level 4: Results

Level 4 considers the impact of training on organisational results. Kirkpatrick (1996) suggests looking at measures such as reduced costs, higher productivity, improved quality, lower employee turnover among others. With this comes even more complicating factors as other dynamics may contribute to the same measure.

2.7.2 Application of Kirkpatrick Model to measure effectiveness of training

This model can be considered for evaluating the effectiveness of the Learning Factory in imparting Business Improvement skills to a mining workforce. This can be done practically by measuring against each criteria and suggestions are provided in literature on how this can be achieved. This is summarised in Table 2.3.

Table 2.3: Examples of Kirkpatrick Model application (Bates, 2004), (Farjad, 2012), (Mollahoseini & Farjad, 2012)

Level	Criteria	Measure	Examples
1	**Reaction**	Assessment of training participants reaction to the program	Satisfaction of participants with training program – relevance & quality
2	**Learning**	Quantifiable indicators of the learning that has taken place during the course of the training	Assessments before and after training
3	**Behaviour**	Address the extent to which knowledge and skills gained in training are applied on the job	Improved results/performance in the immediate place or line of work
4	**Results**	Impact of training on the broader organisational goals and objectives	Improved financial results in the organisation

2.8 Summary

In Chapter 1, a case was made for Lean implementation in mining. In this chapter, various literature has been reviewed. The foundations of Lean were explored and a Lean framework was selected to determine which Lean tools have been implemented in previous Lean implementations in mining. It was found that the principles of Elimination of Waste and Creative Involvement of the workforce were the two most applied Lean Principles in the case studies reviewed. In addition to the tools implemented, the benefits, challenges and success factors for Lean implementation in mining were gleaned from these case studies.

Given the disruptive nature of Lean implementation programs, the next step was to analyse the success factors against a change management framework to identify what aspects of the change management model can be considered to improve on success rates of Lean implementations. Using the ADKAR model, a gap in providing knowledge and ability to employees was found. This is because one of the success factors for Lean implementations is training and experience. A need for a method that builds Lean capability in a mining workforce was recognised and Learning Factories were chosen to fulfil this need after looking at their success in manufacturing industries. Lastly, the Kirkpatrick model was chosen as a tool that can be used to evaluate the effectiveness of this Lean training in Learning Factories. Figure 2.10 illustrates the key themes coming from literature that form the basis of this study.

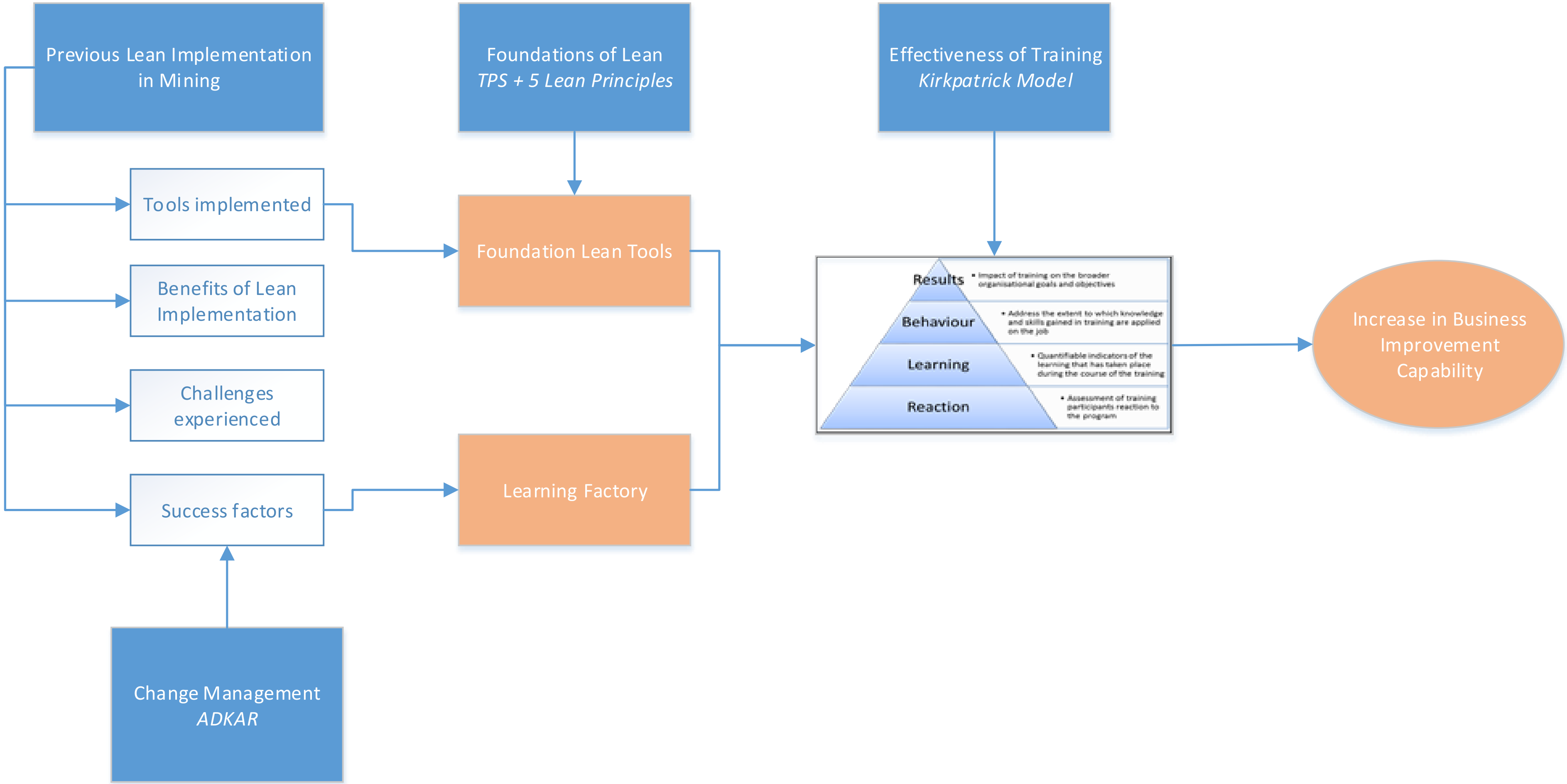

Figure 2.10: Summary of key themes from literature

3 Case study context

3.1 Introduction

The purpose of this chapter is to describe the centre developed by a mining company in South Africa to train employees in Business Improvement (BI) using experiential learning. This section will describe the purpose of this facility and how it achieves this purpose through the modules trained and methods used. In particular, how Learning factories are used in their context. It will also highlight the Lean modules considered as part of this study.

3.2 Learning zones developed in the training centre

The purpose of the training centre is to empower employees with Business Improvement skills that they can apply in their work place. The training at the centre is designed to maximise on experiential learning which as described in the Literature Review and illustrated in Figure 2.7 and Figure 2.8 results in much higher knowledge retention.

The centre has different learning areas and these are identified as zones. There is a foundation zone and three application zones. Figure 3.1 shows a picture of the foundation zone. The first zone is the foundation zone where fundamental BI skills are trained using a Learning Factory that simulates a manufacturing environment. The application zones try to simulate an authentic mining environment where participants can learn by doing and there are three types of environments portrayed namely, maintenance, drilling and mining value chain. By definition, a Learning factory refers to a small scale factory which closely mimics a real factory where participants can learn by doing (Abele, et al., 2015). All the zones at the centre represent Learning factories which mimic real environments in this case, a factory and mining environments.

Figure 3.1: Foundation zone

To ensure effective learning and development, the centre follows a three tier approach that is shown in Figure 3.2. The first zone is the foundation zone where fundamental BI skills are trained using the Model Factory. Participants are then trained in the application zones where an authentic mining environment assists in bridging the gap between theory and reality. Lastly the participants are expected to apply the learnings in the work environment by participating in site-specific BI projects where they receive coaching. The expectation is that these BI skills become part of the day to day work of the organisation.

Figure 3.2: Approach to training and embedding Business Improvement skills adopted by centre

3.3 Modules presented at the training centre

3.3.1 Module development

The development of modules falls outside the scope of this research project as the modules were developed by the mining company. This section will show the modules presented at the centre and how they relate to the Lean principles relevant to a mining organisation as identified in the Literature Review. Table 3.1 shows the suite of Lean specific modules presented at the centre. The Literature Review showed that in mining Lean implementations, the most widely applied principles from the Lean Framework proposed by Lyons, et al., (2011) are those of Waste elimination and Creative Involvement of the workforce. Furthermore, the Literature Review showed that most companies starting out in Lean start with these practices. Most of the Lean practices from these two principles are covered by the modules taught at the training centre and do form the bulk of the modules taught as shown in Table 3.1.

3.3.2 Training provided to case study participants

In light of the training centres' objectives and modules highlighted in the preceding sections, this section will describe the content that participants in this study were exposed to. This curriculum was developed by the centre after evaluating the needs of the audience. The participants comprised of multi-disciplinary and multi-level employees tasked to execute BI projects in their areas of work. This curriculum was presented to participants over a two day period in the foundation zone and the principles and content delivered are shown in Table 3.2.

Curriculum and module development fall out of the scope of this research as this was done by the centre. The researcher sought to observe what was presented by the centre.

Table 3.1: Lean practices and modules taught at training centre

Lean principle from Lean Framework	Lean Practice	Module
Elimination of waste	Seven Wastes	Learning to see and eliminate waste
	Standardized work	Standard Operating Procedures Training
	Total Productive Maintenance (TPM)	Maintenance Strategy
	Value stream mapping	Process mapping From Value Driver Trees to Performance Metrics
	5S and Visual Control	5S and Visual Training
	Poka- Yoke	Error-proofing
	Overall Equipment Effectiveness (OEE)	OEE Analysis and Improvement
	Statistical Process Control	Control chart and capability histogram training
	Quick changeover	Make a process faster
Creative involvement of the workforce	Team-based problem solving	A3 problem solving
	Worker-driven kaizen	Root Cause Analysis Coaching Overcoming resistance to change Collecting information and insights Performance dialogue and feedback techniques Meeting Management
Alignment of production with demand	Theory of Constraints Heijunka – Schedule levelling Pull system – Kanban Takt time	Capacity analysis: Identifying and Eliminating Bottlenecks

Table 3.2: Curriculum for case study participants - foundation zone

Design		
Topic	**Principle**	**Content**
Introduction		Delegates and facilitators introduction
BI context within organisation	**Company BI Model**	Overview of the BI Model Focus on the Measurement Process • Statistical Process Control • Problem solving methodology • Decision making tools used in Process Performance Review
	Business Improvement	What is Business Improvement? Origins of BI methods (Lean, Six Sigma, TOC) Elements of Sustainable BI • Management Infrastructure: BI Model • Mindsets and capabilities: People in the process • Technical system: Object process and macro mapping Types of thinking required in BI
Issue Investigation	**Problem Solving**	Generic process of problem solving and methods A3 concept as a management and communication tool Importance of metric tracking Tools for tracking the completion of actions
		Compiling a problem statement – Kipling method (5W1H -WWWWWH) Macro Map and Value Flow Map Scoping the problem Selecting the primary metric Validating root causes and control actions
	Root Cause Analysis	Fishbone diagram 5 Why's
Waste	**Value vs Waste** **Gemba**	Understanding different types of work Defining the 8 Wastes Preparing for a waste walk and executing Gathering data for value adding vs non-value adding work
Control Action Formulation	**Brainstorming potential control action ideas**	Concept of brain storming (Do's and Don'ts) • Affinity diagrams • Grouping Error Proofing Improvement selection • Ranking and selection tools

3.4 Mapping of training centre approach onto Kirkpatrick model

As mentioned in section 3.2, to ensure effective learning and development, the centre follows a three tier approach that is shown in Figure 3.2. Participants are taken through the foundation and application zones followed by fieldwork at their area of work. This approach is driven by a desire to be effective and the Kirkpatrick model was identified in the Literature Review as an appropriate tool to measure effectiveness. This research will now map the training centre approach to the Kirkpatrick model to display how this effectiveness is achieved and can be measured. This mapping is shown in Figure 3.3. The Kirkpatrick level one and two evaluation of reaction and learning can be evaluated at the training centre itself in the learning zones. The Kirkpatrick level three and four evaluation of behaviour and results respectively can be evaluated back at the operation during fieldwork. This study will look at Level 2 and Level 3 criteria that focuses on evaluating effectiveness by looking at learning and behaviour. Level 1 of measuring reaction is already routine practice at the centre where course evaluation forms are completed at the end of training and processed to review feedback. Level 4 is out of the scope of this study as it involves looking at broader operation data to quantify the impact on financial results and this could require more participants than those in this current study.

Training Centre approach		1 Foundation zone  +	2 Application zones 	3 Fieldwork 	
Kirkpatrick Model	**Criteria**	**1. Reaction**	**2. Learning**	**3. Behaviour**	**4. Results**
	Measure	Course evaluation	Assessment before and after training	Improved results in immediate place of work	Improved organisation financial results

Figure 3.3: Mapping of training centre approach onto Kirkpatrick model

4 Research Methodology and Procedure

4.1 Introduction

The purpose of this research is to determine the effectiveness of using the Learning Factory to impart Lean principles to a mining workforce. The relevant Lean principles have been established in Chapter Two and the Learning Factory was identified as a potential tool for training employees on these principles. The effectiveness of training will be measured using aspects of the Kirkpatrick Model.

The first part of this chapter, section 4.2 will look at the research methodology to establish a framework to investigate the problem. It will also look at the relevant research methods to support the study. The second part, section 4.3 will describe the procedure that the researcher followed to obtain the results.

4.2 Research methodology

4.2.1 Research design

Case study research

This research falls into the category of case study research. Case study research is directed at understanding the uniqueness and idiosyncrasy of a particular case in all its complexity (Welman, et al., 2005). The purpose of case study research is to understand one situation in great depth. Schell (1992) describes a case study as an empirical inquiry which investigates a contemporary phenomenon within its real life context.

Data collection methods

Data can be collected quantitatively or qualitatively. In quantitative research predetermined instrument based methods are used to collect performance, attitude and observational data which is validated through statistical analysis (Cresswell, 2003). Qualitative research draws on open ended questions and relies on interview, observation, documents and audio-visual data (Cresswell, 2003). Mixed methods research relies on both techniques. This research will be a mixed methods research whereby data will be collected quantitatively and qualitatively. This is consistent with Iacono, et al., (2009) as they say that case study research relies on multiple sources of evidence and multiple data collection techniques.

4.2.2 Qualitative data collection

Qualitative data can be obtained through various techniques and in this research indirect data will be collected in the form of observations by the researcher as a participant observer.

Observations

Observations will be collected as the researcher will serve as a participant observer with the dual role of experiencing activities of the group and observing and recording the experiences. According to Welman, et al., (2005) the degree of participation can vary from maintaining distance from phenomenon being studied to becoming a member of the inner circle of a group and becoming fully absorbed.

4.2.3 Quantitative data collection

Quantitative data collection will be in the form of questionnaires and process data for the respective projects.

Questionnaires

To measure the Kirkpatrick Level 2 criteria of Learning, the use of before-and-after tests was recommended in the Literature review and will be used in the study. These tests will be in the form of questionnaires.

Welman, et al., (2005) advise that the starting point of developing a questionnaire should include the examination of the theoretical question to be answered followed by drawing up a list of information required to address the problem. Questions to be included in the questionnaire should relate to the research questions. Further, Welman, et al., (2005) suggest that the researcher should seek out as much previous research on the topic or related topics to guide them with developing the questions.

The questionnaires developed would also need to be valid as a Kirkpatrick Level 2 evaluation. Kirkpatrick (1996) provides guidelines on designing evaluations and these are elaborated by Phillips, (2009). There are ten guidelines to be considered when developing a valid Level 2 Evaluation that will correctly measure if learning has taken place and these are highlighted below (Phillips, 2009):

1. Focus on creating Level 2 evaluations that test for understanding not just knowledge
2. Where appropriate, use Level 2 evaluations for reinforcement as well as evaluation
3. Group questions by topic or concept for scoring, but randomize for administration
4. All evaluation items should discriminate between participants who know the material taught really well from those who don't
5. Avoid compound questions that ask for more than one thing
6. Do not test participants on concepts or material that was not covered in the learning program
7. Write all test items the same way the material was taught
8. Provide clear test instructions
9. Allow participants to use test aids during the evaluation, if they use them when performing their job
10. Avoid developing evaluation items that contain trivial information

Further, Phillips, (2009) also gives guidance on the advantages and disadvantages of creating questions using different formats. These formats range between multiple choice questions, true/false questions, fill-in-the-blank questions and unstructured open ended questions. Consideration was given to the ease of grading, ease of design and the desired outcome of measuring understanding. The researcher settled on unstructured open ended questions where the interviewer asks a question without prompting with regards to the range of answers expected. The advantage is that the respondents answer is not influenced by prepopulated answers and provides a platform for testing understanding. When it comes to grading, they are more difficult to score and more time consuming (Welman, et al., 2005).

Time series analysis of process data

Quantitative data will be collected in the form of the process data where participants apply the skills from the Learning Factory on Business Improvement projects. This is consistent with Kirkpatrick Level 3 evaluation of Behaviour. It will be analysed before the Lean intervention and after the intervention to determine if there was any beneficial change. This will be analysed using Statistical Process Control Charts. According to Benneyam, et al. (2003) to identify beneficial change after an intervention, the following three steps should be followed:

i. Determine and define key indicators
ii. Collect appropriate amount of data
iii. Analyse and interpret this data

The use of Statistical Process Control (SPC) charts to analyse the data is preferred as it helps to separate the inherent variability in data that could otherwise mask the impact of an intervention (Benneyam, et al., 2003). This is favourable because one of the challenges of Kirkpatrick Level 3 evaluation pointed out in the Literature Review is that multiple factors can contribute to the change observed making it difficult to single out the effect of training on behaviour. Furthermore, another advantage of using SPC charts in this study over classical statistical methods is that the latter require large amounts of data to be collected over time so that statistical significance tests can be done. With SPC, the statistical significance is analysed in a time series and trends and process changes can be detected earlier (Benneyam, et al., 2003). Inherent variation is identified as ‘common cause variation’ and anything outside this natural variation is ‘special cause variation’ and this can be used to identify the impact of an intervention.

4.2.4 Validity

Validity is the extent to which the research findings accurately represent what is happening in the situation being observed (Welman, et al., 2005). This process ensures legitimacy of results. Validity will be ensured using the following techniques:

- Peer debriefing
- Triangulation
- Statistical inference validity

Peer debriefing

Peer debriefing is described as a process to enhance the credibility of research (Spillett, 2003). This is a process to provide feedback on the accuracy and completeness of the researcher's data collection and analysis process. Spillett (2003) emphasises the importance of trust in choosing debriefers, commitment of all parties to cultivate a high quality product and the developmental nature of the process. Peer debriefing will be used to review the questionnaire and for moderation.

Triangulation

Construct validity of a measuring instrumentation refers to the degree to which it measures the intended construct (measure that which it is supposed to measure) rather than irrelevant constructs or measurement error (Welman, et al., 2005). Triangulation is a technique that is used to test construct validity by using more than one measure of the same construct. Methodological triangulation is a technique that involves using more than one kind of method to study a phenomenon (Bekhet & Zauszniewski, 2012). It has been found to be beneficial in providing confirmation of findings, increased validity and understanding of studied phenomenon (Bekhet & Zauszniewski, 2012). Triangulation of observations and questionnaire grading will be done.

Statistical inference validity

This will be achieved using two tools, namely t-tests and frequencies.

t-tests: Inferential statistics can be used to make conclusions on whether observed difference is statistically significant. The t-tests can be used to determine if there is a statistically significant difference in the sets of data before and after.

This method of significance testing has been chosen as the t-distribution is appropriate for small samples where number of data points is less than 40 (n<40) (Napier-Munn, 2008). The validity of the t-test relies in assumptions it makes about the data one of which is that the populations being compared have the same variance (Napier-Munn, 2008). The f-test is done to validate that the populations compared (the before and after data) have the same variance.

Frequencies: These are used to determine the distribution across categories to see if this distribution is even or clusters around one or two categories. This can be used to assess if there is any impact of averaging in the processing of data collected.

4.2.5 Sampling methods

An appropriate sampling method needs to be determined to support the data collection proposed in section 4.2.2 and 4.2.3. Welman, et al. (2005) define a research design as the plan according to which research participants are obtained and information is collected in order to solve the problem identified. Research design should specify:

- Number of groups that should be used
- Whether the groups should be drawn randomly or people assigned randomly to the groups
- What should be done with the participants

The first step is to define the sample requirement of this research design.

According to Welman, et al. (2005), the population is the total collection of all units of analysis that the researcher wishes to make specific conclusions. In this case, the population will be the employees of a mining operation. A sample must then be chosen from this population. Upon investigation of sampling methods, it was found that this research lends itself to a type of non-probability sampling. In non-probability sampling, the probability that any unit of analysis will be included in a sample cannot be specified (Welman, et al., 2005). Purposive sampling is a type of non-probability sampling where participants are selected based on the research question being asked. Participants are selected based on the researcher's judgement which may be drawn from experience, ingenuity and previous research findings (Welman, et al., 2005). This source further advocates for purposive sampling where the sample size is small as is the case with this research. `Participants for this research will be chosen from a population of mine employees who intend to use Lean skills to effect process improvement.

4.3 Procedure

This section presents the actual method carried out by the researcher in the execution of the study.

4.3.1 Research approach

This research will be a typical case study that looks at mining employees with the researcher serving as a participant observer. This research will look at a particular case of mining employees being exposed to the foundational Lean Principles through the Learning Factory and being assessed to investigate the effectiveness of the Learning Factory in imparting these principles.

With the boundaries highlighted by Welman, et al., (2005) in mind, the boundaries for this research are the workforce that will have participated in the Learning Factory and the specific Lean principles introduced in the factory. The collected data will be analysed for recurring patterns and this will be elaborated on further. Triangulation will be one of the tools used for data validation.

4.3.2 Developing the research instruments

Research instruments that will be used are questionnaires, observations table and process data from improvement projects. This section will describe the development of the instruments.

Development of Questionnaires

Group administered questionnaires will be most suited because participants will be trained as a group and will work on the improvement project as a group thus they will be geographically located in the same place. Further advantages are that the researcher will be present to offer assistance and clarity where needed. As prescribed by Kirkpatrick Level 2 Evaluation (Kirkpatrick, 1996), a before-and-after test will be used and so two questionnaires will be handed out. Firstly before training commences to get information on current comprehension on Lean techniques, then after training to measure understanding based on training.

Based on the two approaches of developing questions suggested by Welman, et al., (2005) and Phillips, (2009) described in section 4.2.3. The researcher proposed the hybrid approach shown in Figure 4.1. The questions were based on the previous research of appropriate Lean principles for mining and they needed to be unstructured open ended questions as far as possible.

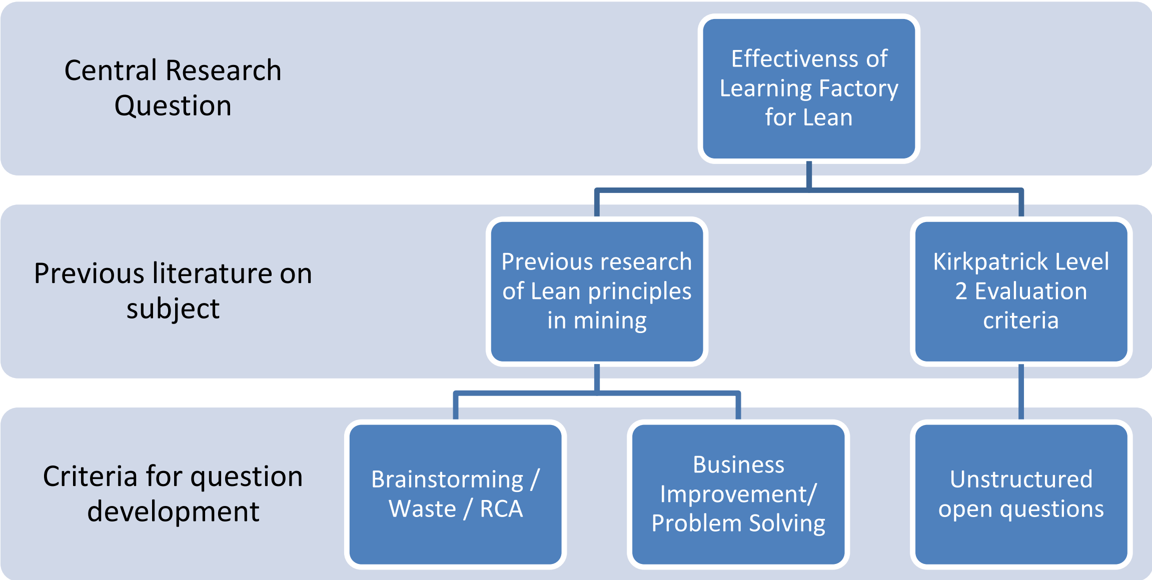

Figure 4.1: Formulation of questionnaire

The questionnaire has been designed to establish the employees understanding of the practices in Table 3.2 before being exposed to the Learning Factory and after being taught. It will consist of a series of questions for each Lean practice.

The respondents' literacy level was a significant consideration as English is not the first language for the majority of the participants and education levels were also widely distributed depending on the role of the participants. Care was taken to ensure that words and concepts that the respondents are familiar with were used.

The first questionnaire before participants are exposed to the Learning factory has five questions to test initial understanding while the second questionnaire has eleven questions. The second questionnaire has the five questions from the first questionnaire and additional questions. From the approach shown in Figure 4.1, the questions were established for each principle as shown in Table 4.1. The questions highlighted in green are the five questions in the pre-test questionnaire.

Table 4.1: Construction of questions for before-and-after questionnaires

Principle	Questions	Reasoning
Business Improvement	What is your understanding of Business Improvement?	To determine if they have understood where BI fits in
	What are the three types of work?	
Waste	What is the definition of a waste?	To establish if they have understood the concept of waste and can identify it
	Why is it important to identify and eliminate all wastes in the process?	
	Name any four of the commonly observed sources of waste.	
Problem Solving	What statements/tools would you consider when coming up with a problem statement to define a problem?	To check if participants can follow a structured problem solving process to determine the problem. Also to check if the participants appreciate the benefit of structured approach.
	What is the importance of having structured problem solving procedure in place to determine root cause?	
	Why is it important to validate potential control actions?	
Root Cause Analysis	Name one tool used to determine root causes?	To check if the participants can identify root causes using tools and further validate the causes.
	Why is it important to validate root causes?	
Brainstorming	What is the benefit of brainstorming?	To establish if the benefit of brainstorming is appreciated

These questionnaires are shown in Appendix 9.1.

Peer debriefing

Peer debriefing can be used throughout the research but in this research it was used in two stages. Firstly, peer debriefing was used to evaluate the questionnaires that were used in the surveys. This approach ensured the integrity of the questions from the onset and that the right data that will assist in answering the research question is collected. The outcome from this peer debriefing is shown in the results section 5.1.1 when the assessment of a questionnaire is presented.

The second instance where peer debriefing is used is for moderating the grading of questionnaires to validate the quality and consistency of the grading process. This would guard against bias from the examiner. A random sample of questionnaires was moderated and the outcome is shown in Appendix 9.2.

The first peer debriefer is a Principle BI Training Program Designer. He was previously appointed as Sasol Mining Enterprise Lean Six Sigma Master Black Belt. In the role he executed, trained and coached others through Lean Six Sigma projects across a mining complex.

The second peer debriefer is a Senior Operations Excellence Consultant. She graduated with a BSc. Engineering (Industrial) Honours Degree (Cum Laude) from the University of Pretoria. She has been involved in rolling out Lean principles across several mining operations.

Observations

Earlier in section 4.2.2 it was highlighted that as a participant observer, the degree of participation can vary from maintaining distance from phenomenon being studied to becoming a member of inner circle of group and become fully absorbed. The researcher will take both approaches and be a member of the classroom activities at the Learning Factory and will be fully absorbed in the team. When it comes to implementing the projects, the researcher will maintain a distance and check in with the different groups to keep up with progress and collect observations.

The observations will provide secondary data about the participants' response to the training at the Learning Factory and their ability to apply the learning. This data can be triangulated with the results from the questionnaires thus providing a means of validation. Given the benefits of this source of data, a structured observations table was developed with justification for the observation criteria chosen as shown in Table 4.2. This table was used during the training at the Learning Factory and during application of the learning at project kick-off. During the latter, the researcher added more criteria as the participants engaged with the content in defining their problems.

Table 4.2: Developing the observations table

Observation Criteria	Justification
Ability to relate Business Improvement to their environment	Demonstrates understanding of BI to their own environment, extends out of the classroom
Ability to identify and differentiate between the types of waste	A measure of how well participants can practically identify waste in the activities
Are participants able to follow a structured problem solving methodology?	This principle translates into application of learning into the workplace as it is easier with a structured methodology
Do participants know how to use RCA tools?	While they may know the tools, this seeks to investigate if they can use them correctly.
Ability to manage bias in brainstorming	This is to test if they can brainstorm effectively

Process Data

As mentioned in section 4.2.3, data needs to be collected to identify if a beneficial change has been realised after an intervention.

The approach by Benneyam, et al., (2003) will be followed and the participants will select the key indicators based on the problem they are solving in their project. With this they will collect the data which the researcher will then also analyse and interpret using SPC charts.

4.3.3 Ethical Clearance

The ethical considerations for conducting research on human subjects and using company resources were adhered to as laid out by the University of the Witwatersrand. Ethics clearance was obtained from the Human Research Ethics Committee (Non-medical) (HREC) as this research involved human participants and the ethics clearance number is MIAEC 008/16. This was obtained through the School of Mechanical, Industrial and Aeronautical Engineering. There are two formal clearances required for this research, the first from the company granting permission for the research to be conducted and the second from participants granting permission and consent. These clearances were prerequisite for data collection and can be found in Appendix 9.4. In addition to the formal clearances, the researcher undertakes to abide by ethical codes when conducting this research.

4.3.4 Pilot study

The first group through the Learning Factory served as a pilot study to test the effectiveness of the instruments. Minor adjustments were made to the instruments before group two was tested. The adjustments were small enough that this group was considered in the full study analysis.

One of the adjustments was taking into consideration a point raised by Welman, et al. (2005) on ensuring that the question is appreciable to all respondents. The pilot study picked that the classification to identify the job level of the respondent was not adequate as it excluded some roles and levels.

Secondly, some of the questions on the post-training questionnaire were found to be ambiguous when the responses were analysed and these were rephrased without compromising on the Lean principle being assessed. Adjusted questionnaires are available in Appendix 9.1.

4.3.5 Full study

This section describes the process followed by the researcher to collect data. The participants that were involved in the study will be discussed first followed by the data collection process.

Research sample and participants

Two groups of mining employees were exposed to the Learning Factory and were participants in this study. The first group also formed the pilot study and comprised of employees working at a mineral processing operation. It comprised of engineering personnel like artisans and section engineers as well as production crew namely processors and metallurgists. As they were piloting a new methodology for future Business Improvement projects, they had a team of Business Improvement specialists present and participating as well. The second group comprised of employees who work in operation support services and comprised of administrators, supervisors and analysts who provided centralised services to multiple operations.

The demographics of the participants in the two groups are shown in Table 4.3. The operations support services group was slightly bigger than the mineral processing operations group. A total of 26 people participated in this study. This is considered to be a small sample size and could be a limitation to the study.

Table 4.3: Demographics of participants in the study

Group	Environment	Employment Description	Number of Participants	Total	% split
1	**Mineral Processing Operation**	Artisans & Processors	5	12	46%
		Section Engineers & Metallurgists	3		
		BI Specialists	4		
2	**Operations Support Services**	Administrators	7	14	54%
		Supervisors	3		
		Analysts	4		
		Total	**26**	**26**	**100%**

The study also considered how well the material is understood across employment levels so the participants were grouped according to employment levels. The Requisite Organisation Level of Work Model by Dr. Elliot Jacques was chosen to describe the different employee levels as it is consistent across different environments and in this case the technical and support environment are different (Macdonald, et al., 2014). Furthermore, the organisation under study also uses this model for defining hierarchy. The Level of Work employment levels considers the differences in job complexity, time horizons in which decisions are made by the people in the roles among other factors (McMorland, 2005). The Level of Work model has universal application and works across cultural and environment barriers. This is because its basis is that the complexity of work grows as time span extends and this is the time frame within which accountability is deliverable (McMorland, 2005).

While this is a seven level model of management hierarchy with time frames ranging from hours (Level 1) to more than 50 years (Level 7), the first three levels are concerned with operational work (Macdonald, et al., 2014). Participants in this study are working at operational level so these first three levels will be elaborated more in Table 4.4.

Table 4.4: Levels of work (1 – 3) (McMorland, 2005) (Macdonald, et al., 2014)

Level	Time span	Theme	Objectives	Outcomes	Roles
1	0 – 3 months	Quality	Hands on – completing concrete procedural tasks correctly	Day to day provision of services or manufacture of goods according to predetermined standard operating procedures	Frontline staff/ supervisor
2	3 -12 months	Service	Monitoring and diagnosis of operational processes	Capacity to inform Level 1 of work requirements and respond to events not covered by operating rules	First line managers
3	1 – 2 years	Practice	Discerns trends to develop and refine existing systems	Defining best practices and defining systems and structures that make this possible.	Function heads

Table 4.5 shows the participants grouped according to Levels of Work. 58% of the participants are involved with Level of Work 1 complexity with the balance being involved in Level 2 complexity work. There was need to distinguish the group of BI specialists performing Level 2 Work as they have

discipline specific knowledge already that could skew the results obtained. The higher the Level of Work, the more senior the employee. Splitting the Level 2 Work employees into two groups results in smaller numbers of participants which may compromise data validity and reliability. Using the t-test to assess the statistical validity becomes significant and this method has been found to be suitable for small sample sizes (Napier-Munn, 2008).

Table 4.5: Demographics of participants according to employment levels

Employment Level	Employment Description	Number of Participants	Total	% split
Level of Work 1	Artisans & Processors	5	15	58%
	Administrator	7		
	Supervisor	3		
Level of Work 2	Section Engineers & Metallurgists	3	7	27%
	Analysts	4		
Level of Work 2 - BI Specialists	BI Specialists	4	4	15%
	Total	**26**	**26**	**100%**

Collection of data during implementation

Following the training at the centre, the groups were expected to identify improvement initiatives in their workplace they would implement. They had to follow a sequence which is summarised below and observations were made during this implementation:

- Have a project kick-off session where they would launch the project.
- They were expected to use the problem solving methodology from the training to structure their project
- Identify relevant metrics to track results of intervention

4.3.6 Data Processing

The next section will describe how the data collected from questionnaires, observations and process data was processed and thereafter analysed.

Grading and Moderation

A template for grading the questionnaires was developed and was used to examine answers provided by the respondents. The grading criteria was consistent with that used by Swart (2015) for grading questionnaires on Lean principles for warehousing employees. Swart used four categories for grading the responses and described the expectation for each category as shown in Table 4.6. An addition to the criteria by Swart (2015) is the colour coding of each coding to make it easier for the reader to interpret the score. This colour coding is used in tables and graphs in the results section. Red is used to identify the not understood category, orange for the partially understood grading, yellow for understood grading and green shows the principle is in the well understood category.

Table 4.6: Grading criteria for questionnaire responses (Swart, 2015)

Grading category	**Description**	**Grading Range**	**Colour coding**
Not understood	The Lean principle / method is not known, misunderstood or explanation / answer to the question is below a grading level of 25%.	1.0 < grade ≤1.5	
Partially understood	The Lean principle / method is only partly understood, where the participant is aware of it, but explanation / answer is at a grading level below 50%.	1.5 < grade ≤2.5	
Understood	The Lean principle / method is known and the participant is able to explain / answer the question correctly. However, some shortcomings exist and the answer is below a grading level of 75%.	2.5 < grade ≤3.5	
Well understood	The Lean principle / method is well known and fully understood. The participant is able to explain / answer the question without any shortcomings. The answer is above a grading level of 75%.	3.5 < grade ≤4.0	

Moderation: The graded questionnaires were also moderated and examples of moderated questionnaires are shown in Appendix 9.2. The moderation was done by the second peer debriefer. For more than 88% of the questions the scoring was within +/- 0.5 which meant that the score was in the same category for most of the time. As such there were minor changes to the grading with the feedback from moderation.

Observations

The observations collected from the two groups of participants were recorded using the observations table. Two sets of observations were done to measure Kirkpartick Level 2 and Level 3 evaluation for each group. Some of the raw data is available in Appendix 9.6.The data was presented in a table with both groups' observations to make it more manageable.

Process Data

Metrics were identified by the group executing the BI project. These were made available to the researcher to interpret using SPC charts.

4.3.7 Analysis

The last step is to analyse the data and this was done as follows:

a) Assessment of each questionnaire and recording data, then calculating the average score for each participant and for each principle
b) Comparing before and after grades across groups and then across hierarchy levels
c) Evaluating the frequency distribution to ensure the averaging is not skewing the data integrity
d) Using t-tests to determine the statistical confidence of the changes before and after training.
e) Reporting on summarised observations at both Learning Factory and at project implementation
f) Collecting processing data and using SPC charts to evaluate
g) Lastly, one step triangulation was applied – across-method triangulation where both quantitative and qualitative methods were combined

4.3.8 Limitations of method

Several limitations are apparent in method presented that could lead to shortcomings in the results sections. These limitations are described next.

Subjectivity of observations

The researcher served as a participant observer and this data collection method is limited as it relies on the subjectivity of the observer. Iacono, et al., (2009) suggest that the onus is on the researcher to manage the subjectivity and present and process the evidence objectively. This was partially mitigated by peer debriefing of the questionnaires during development and by moderation. Visual observations were taken to be secondary source of data used for triangulation to further manage this subjectivity. These actions do not completely remove the subjectivity but attempt to keep it in check.

Literacy levels of respondents

This study looked at employees at different levels in the organisation and with wide ranging literacy levels. There was a mix of semi-skilled and skilled participants and the understanding of the questionnaire and the content delivered in the Learning factory could have been affected by this difference. Facilitators made an effort to seek out understanding during training.The pilot study highlighted a few questions that could be improved and the questionnaire was refined the next group of participants. The researcher was also available to provide clarity as required.

Sample selection

Purposive sampling used in this study is also affected by researcher subjectivity and affects the representativeness of the samples. In this study, the researcher did not choose the participants but observed the groups that came to be trained at the centre. This approach further cements this research as a case study as it was limited to the cases (groups of participants) that presented themselves at the centre.

Number of participants

A decision was taken to split employees' performing Level 2 work into two groups to separate BI discipline specialists from other Level 2 employees. This resulted in some groups having smaller number of participants namely, eleven Level 2 employees and four Level 2 BI specialist employees. These smaller numbers may compromise data validity and so statistical tests designed for small sample sizes such as t-tests were used to minimise this effect.

5 Results

The results are presented in two main sections according to how the study was done. Firstly, the results from Kirkpatrick level 2 evaluation of Learning are presented followed by the results from Kirkpatrick level 3 evaluation of Behaviour. Lastly a conclusion of this section is given where the results are summarised.

5.1 Results of Kirkpatrick Level 2 evaluation of Learning

This section will present the results from these questionnaires as well as visual observations made by the researcher in this period.

This section includes the following:

- Grading of questionnaires and peer debriefing feedback in Table 5.1
- Comparison of the two groups of participants in Table 5.2, Figure 5.2 to Figure 5.3
- Comparison of understanding of Lean principles before and after training shown in Figure 5.4 with grades shown in Table 5.4 to Table 5.8
- Frequency distribution of grades in Figure 5.5 and Figure 5.6
- t-test results obtained in Table 5.3
- Comparison of understanding across hierarchy levels in Figure 5.7 to Figure 5.10
- Visual observations made by the researcher in Table 5.9

5.1.1 Assessment of questionnaires

Questionnaires were assessed according to the grading criteria presented in Table 4.6 which was also peer-debriefed. The post-test questionnaire with model answers was submitted to the first peer debriefer for review and proposed changes are highlighted in blue in Table 5.1. The updated model answers were then used for grading. The graded questionnaires were also moderated and examples of moderated questionnaires are shown in Appendix 9.2. Table 5.1 shows an example of how the questionnaires were graded using the criteria in Table 4.6. Appendix 9.2 shows the grades from the assessments for all participants.

Table 5.1: Example of assessment of questionnaire – post training

Place of Work – Mineral Process Operation Employee position – Artisan				
Question	**Ideal Answer and Peer-debriefing comments**	**Given Answer**	**Score**	**Grading category**
What is your understanding of Business Improvement?	*A methodology to improve business processes.* *A structured approach to improve business processes in the eye of the customer to ensure effective and efficient results.*	Is a structured approach or system to improve the value of the business of all stakeholders and investors	4.0	Well understood
What are the three types of work?	*Value Adding Work (VA), Non-value adding work - incidental (NVA- incidental), Non-value adding work-waste (NVA – waste)*	Technical system Mindset & Capability Management Infrastructure	1.0	Not understood
What is the definition of a waste?	*Anything other than the minimum activities and materials necessary to get the job done immediately, right the first time and to the satisfaction of the customer. Any non-value adding activity in the process.* *NB: There are non-value adding activities that are incidental to the process*	Is the time spent not doing the specific or direct tasks, whilst we move around looking for spares.	1.5	Not understood
Why is it important to identify and eliminate all wastes in the process?	*To create a process/product/service that is value-adding, waste free and satisfactory for the customer. Most important it serves time and money.* *To optimise value add by minimising non-value add activities that are incidental and eliminate waste activities.*	In order to reach the target to fulfil the customer's order	2.0	Partially understood
Name any four of the commonly observed sources of waste.	*Overproduction, waiting, intellect, over-processing, inventory, motion, rework, transportation*	Waiting, motion, transportation, inventory	4.0	Well understood
What statements/tools would you consider when coming up	*Use of tools such as WWWWWH, problem scoping and, selecting primary metric.*	Fishbone tool	1.0	Not understood

Place of Work – Mineral Process Operation Employee position – Artisan				
Question	**Ideal Answer and Peer-debriefing comments**	**Given Answer**	**Score**	**Grading category**
with a problem statement to define a problem?				
What is the importance of having structured problem solving procedure in place to determine root cause?	*It provides an official process to detect and resolve problems as they occur.* *It provides a common language that is replicable that allows for alignment of problem solving techniques and quicker problem solving as problems occur. Examples are the PDCA/ A3*	To avoid the repeats and meet our production targets	1.0	Not understood
Name one tool used to determine root causes?	*Fishbone* *5-why analysis*	Fishbone	4.0	Well understood
What is the benefit of brainstorming?	*Develop as many ideas as possible. Promote creativity and openness to get the most value out of the group.* *NB: Gives everyone a voice*	It's the information sharing and searching for the problem solving root	2.5	Partially understood
Why is it important to validate root causes?	*To ensure that you are not treating symptoms so that after treatment you do not have repeats.*	To ensure that the root cause analysis is of good effect to avoid repeats	4.0	Well understood
Why is it important to validate potential control actions?	*To determine if the actions are effective (is it going to work) and plausible (is it worth the effort).*	To ensure that the time is eliminated from the waste	1.0	Not understood

5.1.2 Comparison of the two groups

In analysing the results from the questionnaires, the approach will be to first compare the performance of the two groups. From this high level, the analysis will become more granular to compare understanding of each Lean principle by the different roles. Some graphs used in this results section have been colour coded according to the grading template presented in Table 4.6. From bottom up, grades in the light red band show that the concept was not understood, while the orange band shows that they were partially understood, yellow means it was understood and green is for well understood.

The average participants' overall understanding of Lean principles before and after exposure to the Learning factory was measured from the survey scores and is presented in Figure 5.1. Before exposure to the Learning factory, both groups showed that they partially understood Lean Principles with Group 1 having a greater understanding than Group 2. After the training in the Learning factory, both groups showed that Lean Principles were now understood and attained a similar score. These results are discussed further in section 6.1.

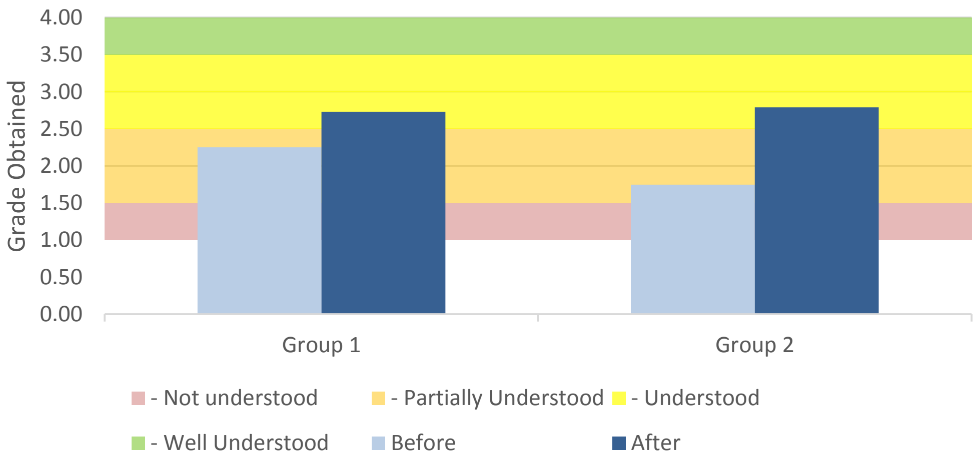

Figure 5.1: Comparison between the two groups overall Lean understanding

The next step is to consider how each group did on the individual Lean principles from an overall group perspective and this is displayed in Figure 5.2 and Figure 5.3 for Group 1 and Group 2 respectively. The clustered bar graph has been used to show how the values changed over the two periods evaluated. In this case the evaluation is a comparison of participants' understanding before training and after training. Both Figure 5.2 and Figure 5.3 show that participants understanding of all Lean principles after training was higher than their understanding prior to the training.

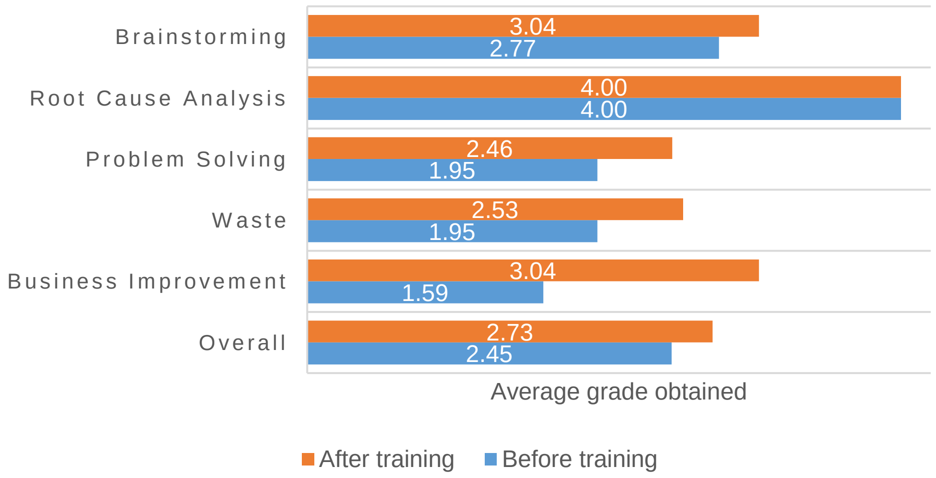

Figure 5.2: Learning factory group 1 results before-and-after training

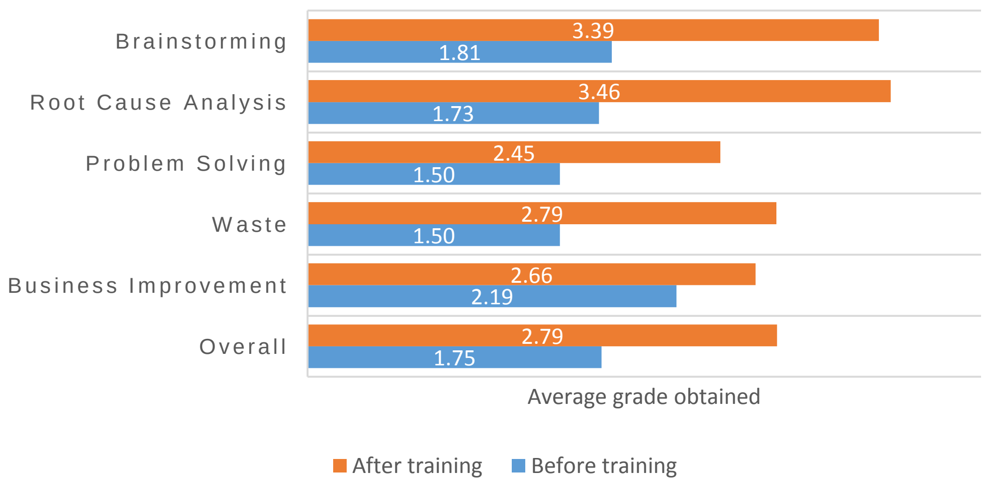

Figure 5.3: Learning factory group 2 results before-and-after training

Table 5.2 shows the grades and standard deviation for each group and the relevant grading category. It is also colour-coded in the same colours as Figure 5.1 previously displayed to make it easy to compare the performance attained. The tables also show the percent change in understanding after training in the Learning Factory.

Table 5.2: Grading of Lean Principles and %change in grading for Group 1 and Group 2

Group 1							
Q'naire	**Grading**	Overall	Business Improvement	Waste	Problem Solving	Root Cause Analysis	Brainstorming
Before	**Average Grading**	2.3	1.6	2.0	2.0	4.0	2.8
	Std Dev	0.5	0.9	0.9	0.8	0.0	0.7
	Grading Category	Partially Understood	Partially Understood	Partially Understood	Partially Understood	Well understood	Understood
After	**Average Grading**	2.7	3.0	2.5	2.5	4.0	3.0
	Std Dev	0.3	0.9	1.3	1.2	0.0	0.5
	Grading Category	Understood	Understood	Partially Understood	Partially Understood	Well understood	Understood
% change in grading		**21%**	**91%**	**30%**	**26%**	**0%**	**10%**
Group 2							
Before	**Average Grading**	1.7	2.2	1.5	1.5	1.7	1.8
	Std Dev	0.5	0.8	0.6	0.6	1.1	0.8
	Grading Category	Partially Understood	Partially Understood	Partially Understood	Partially Understood	Partially Understood	Partially Understood
After	**Average Grading**	2.8	2.7	2.8	2.5	3.5	3.4
	Std Dev	0.3	1.2	1.0	1.2	1.1	1.0
	Grading Category	Understood	Understood	Understood	Partially Understood	Understood	Understood
% change in grading		**60%**	**21%**	**86%**	**63%**	**100%**	**88%**

5.1.3 Statistical analysis of survey results

The data obtained from the surveys has been presented graphically in the previous section. All graphs show an improvement in understanding after participants have been trained in the Learning Factory. Statistical tools can be used to determine the significance of the observed differences in understanding before and after the training. The t-test for Two Means was used to compare the overall grades obtained for Group 1 and Group 2 for overall Lean understanding as well as understanding of each of the Lean principles. Some of the assumptions about the data made by the t-test were tested to ensure the test is valid and in particular the populations being compared had the same variance. This was achieved by performing an f-test on the populations being compared. Results of f-test and t-test calculations are shown in appendix 9.5.1

A 1-tailed t-test to test the significance of a change in understanding was selected as it is suitable for small samples (Napier-Munn, 2008). Results are shown in Table 5.3 and can be related to the data displayed in Figure 5.1, Figure 5.2 and Figure 5.3. This is the same data presented in the different sections of the results in different granularity depending on what is being analysed.

Table 5.3: t-test results to determine significance of improvement in understanding after training

	Group 1 - Mineral Processing Operation			Group 2 - Operations Support Services		
	% increase in understanding	t-test confidence	Significant Improvement?	% increase in understanding	t-test confidence	Significant Improvement?
Overall	21%	94%	No	60%	100%	Yes
Business Improvement	91%	100%	Yes	21%	84%	No
Waste	30%	96%	Yes	86%	100%	Yes
Problem Solving	26%	96%	Yes	63%	100%	Yes
Root Cause Analysis	0%			100%	100%	Yes
Brainstorming	10%	85%	No	88%	100%	Yes

As discussed in section 5.1.2, Group 2 showed a greater improvement of 60% increase in overall in understanding than Group 1 which had 21%. The t-test showed that the increased improvement demonstrated by Group 1 is statistically insignificant. The same applies for the brainstorming principle observed in Group 1 where the 10% increase is also not significant. The Root Cause Analysis principle did not record a change in understanding as the principle was already well understood by Group 1 and as such, the t-test is invalid. Group 2 improvements were all statistically significant with the exception of the principle of Business Improvement which has smallest increase in understanding of 21% and was found to be statistically insignificant.

5.1.4 Lean principles results

The following sections will look at each Lean Principle and consider how well it was understood by each of the employee groups that participated in this study. It considers participants from both groups simultaneously as identified according to their levels of work shown in Table 4.5.

Figure 5.4 shows radar charts that compare Lean understanding of each principle before training and after training for the different groups of employees. The gap in understanding is the difference between the two points for each group. The blue line shows the understanding of each principle before training and the red line the understanding of the principle after training. In all the charts the blue line is inside the red line showing a lower initial understanding before training.

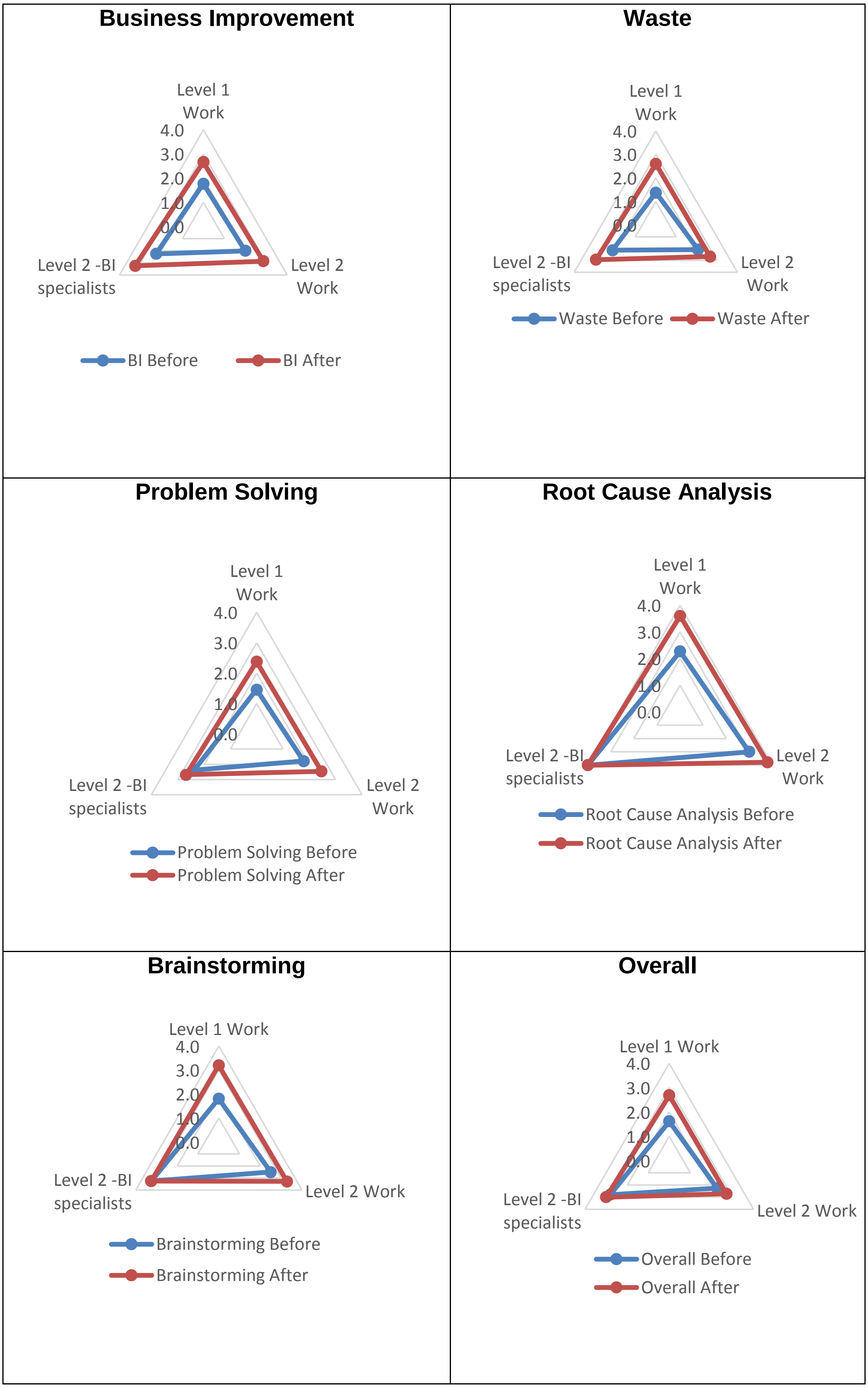

Figure 5.4: Gap in understanding of Lean principles at different levels

The results presented in Figure 5.4 are illustrated in Table 5.4 - Table 5.8 with corresponding category grading for the grades obtained. They also show the % change in understanding after training in the Learning Factory. These results are discussed further in section 6.1.1to 6.1.5.

Table 5.4: Business Improvement principle survey results

Business Improvement				
Q'naire	**Grading**	**Level 1 Work**	**Level 2 Work**	**Level 2 - BI Specialists**
Before	**Average Grading**	1.8	2.0	2.3
	Grading Category	Partially Understood	Partially Understood	Partially Understood
After	**Average Grading**	2.7	2.9	3.3
	Grading Category	Understood	Understood	Understood
% change in grading		50%	43%	44%

Table 5.5: Waste principle survey results

Waste				
Q'naire	**Grading**	**Level 1 Work**	**Level 2 Work**	**Level 2 - BI Specialists**
Before	**Average Grading**	1.4	2.1	2.1
	Grading Category	Not understood	Partially Understood	Partially Understood
After	**Average Grading**	2.6	2.7	2.9
	Grading Category	Understood	Understood	Understood
% change in grading		88%	28%	38%

Table 5.6: Root cause analysis principle results

Root Cause Analysis				
Q'naire	Grading	Level 1 Work	Level 2 Work	Level 2 - BI Specialists
Before	Average Grading	2.3	3.0	4.0
	Grading Category	Partially understood	Understood	Well understood
After	Average Grading	3.6	3.8	4.0
	Grading Category	Well understood	Well understood	Well understood
% change in grading		59%	26%	0%

Table 5.7: Brainstorming principle results

Brainstorming				
Q'naire	Grading	Level 1 Work	Level 2 Work	Level 2 - BI Specialists
Before	Average Grading	1.8	2.5	3.3
	Grading Category	Partially understood	Partially understood	Understood
After	Average Grading	3.2	3.3	3.3
	Grading Category	Understood	Understood	Understood
% change in grading		77%	31%	0%

Table 5.8: Problem solving principle results

Problem Solving				
Q'naire	**Grading**	**Level 1 Work**	**Level 2 Work**	**Level 2 - BI Specialists**
Before	**Average Grading**	1.5	1.8	2.4
	Grading Category	Not understood	Partially understood	Partially understood
After	**Average Grading**	2.4	2.5	2.7
	Grading Category	Partially understood	Partially understood	Understood
% change in grading		63%	38%	13%

5.1.5 Frequency distribution of grades obtained

Given that the grades presented in the preceding tables are averages, the impact of averaging can be analysed by looking at the frequency distribution of the grades obtained. These are shown in Figure 5.5 and Figure 5.6. The percentages are a measure of the number of participants who obtained that grade. The graphs show that the majority of the grades before training are in the not understood category and partially understood category as displayed by Figure 5.5. This pattern shifts in Figure 5.6 as there is a higher frequency in the last two categories of understood and well understood.

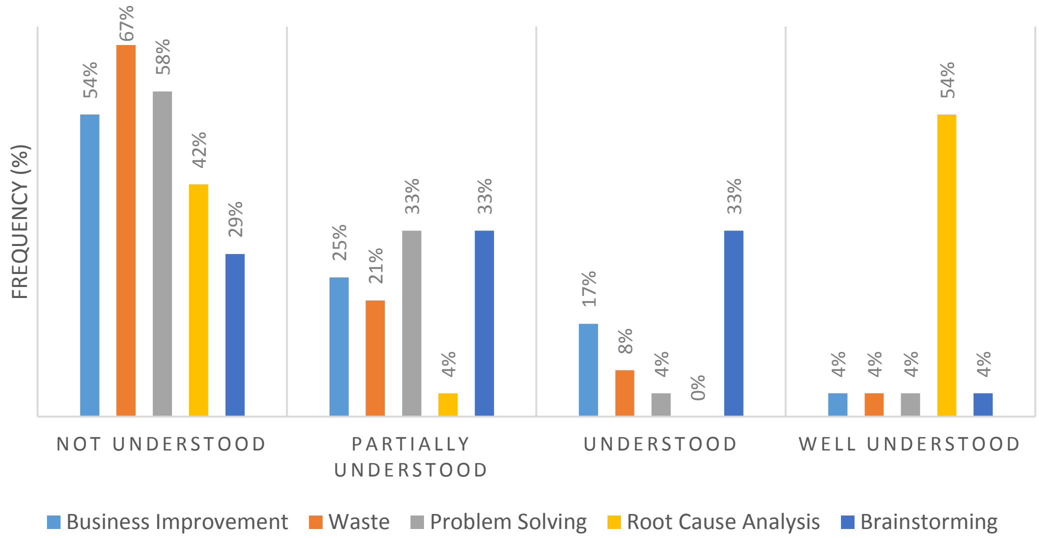

Figure 5.5: Frequency distribution of grades obtained before training

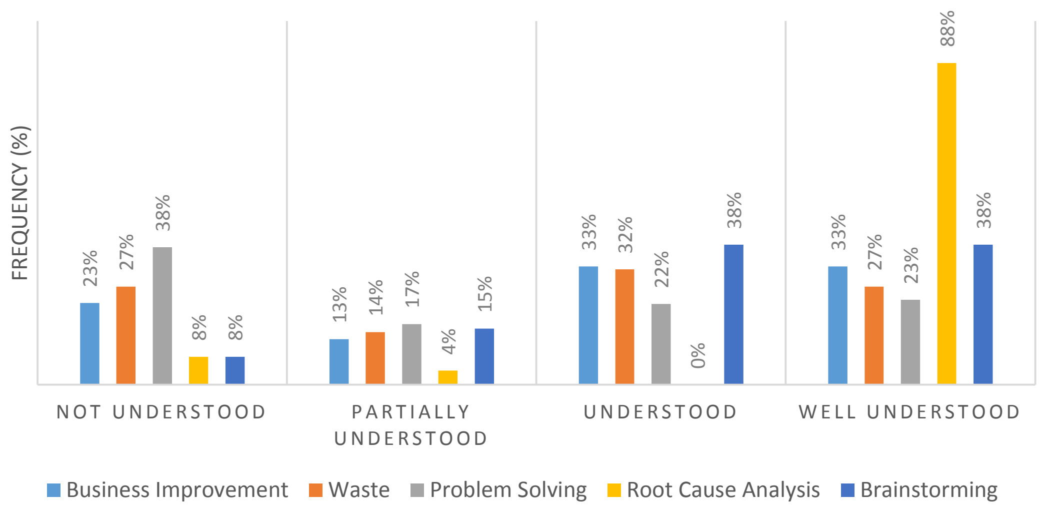

Figure 5.6: Frequency distribution of grades obtained after training

5.1.6 Comparison of Lean understanding at different employment levels

An objective of this research was to determine how well the Lean principles were understood across different employment levels after training in the Learning Factory. The employment levels were classified according to Levels of Work and the participants are either performing Level 1 work or Level 2 work activities in their jobs. As discussed in section 4.3.5, the BI specialists perform Level 2 work but because they are familiar with this subject their results have been reported separately so as not to skew the findings of other participants performing Level 2 work.

Figure 5.7 compares overall Lean understanding for the different levels of work. How the participants in each employment level on the individual Lean principles from an overall group perspective is displayed in Figure 5.8, Figure 5.9 and Figure 5.10 for the different employment levels. These results are discussed further in section 6.2.

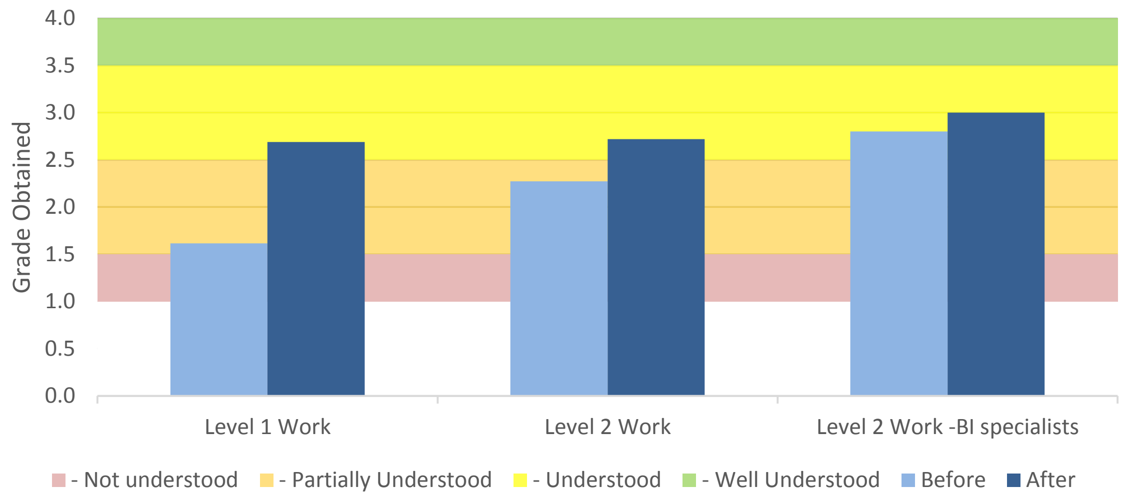

Figure 5.7: Comparison of overall Lean understanding across different employment levels

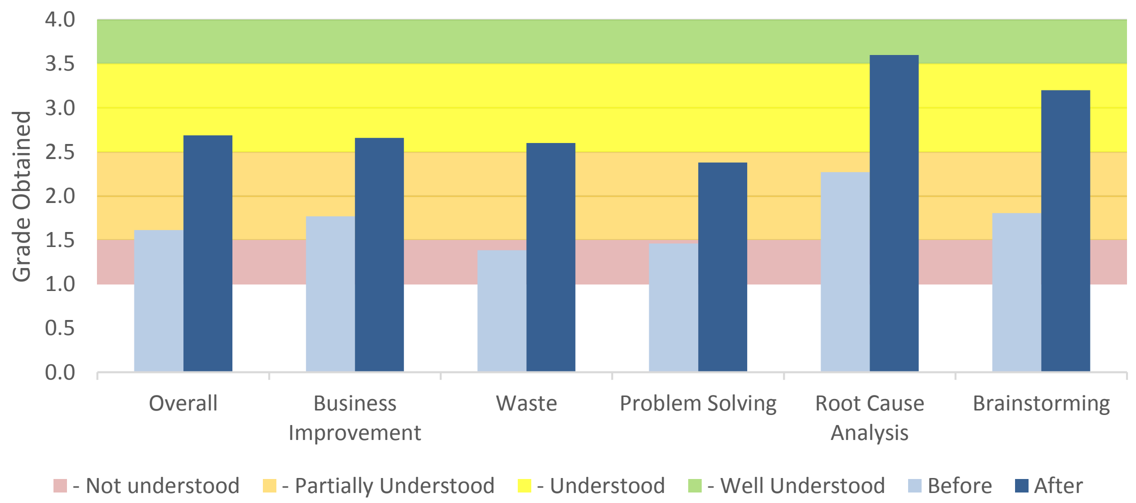

Figure 5.8: Level 1 work employees' understanding of Lean principles

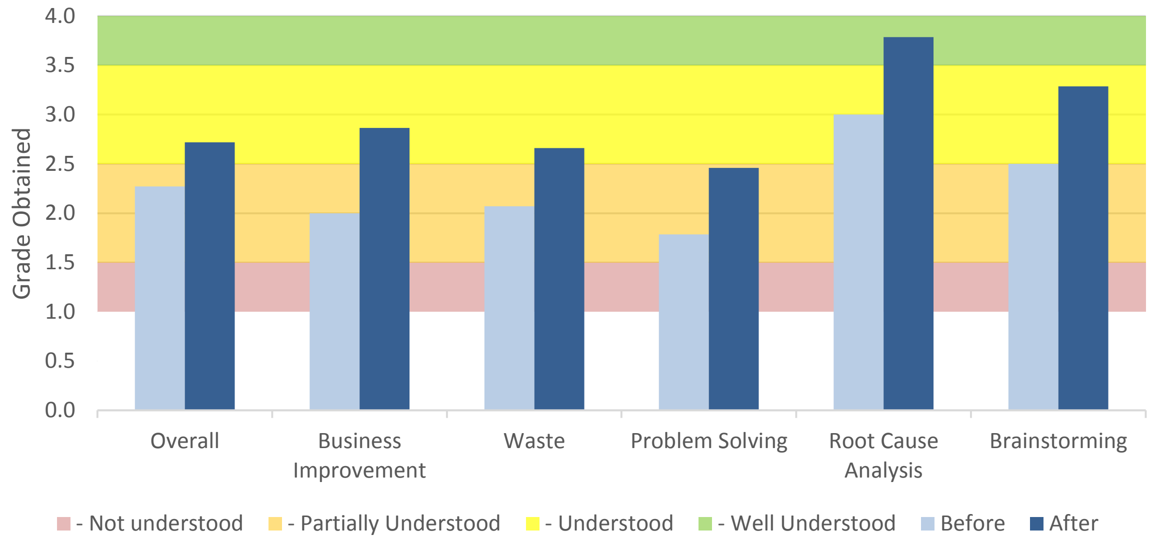

Figure 5.9: Level 2 work employees' understanding of Lean principles

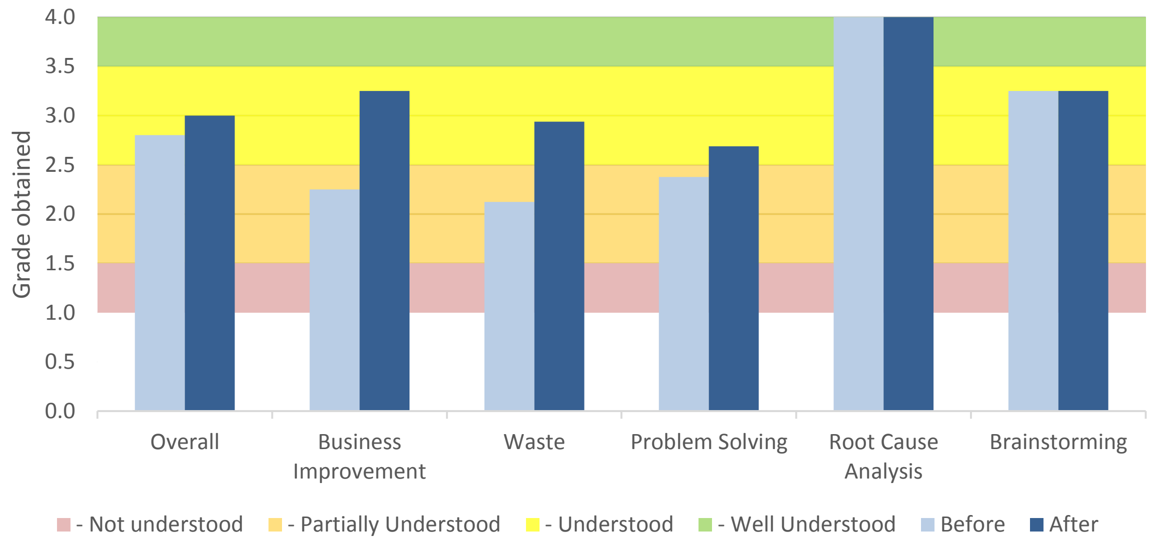

Figure 5.10: Level 2 work BI specialists understanding of Lean principles

5.1.7 Visual observations on Kirkpatrick Level 2 evaluation of learning

Observations by the researcher who was a participant observer in this case study were recorded. According to Kirkpatrick (1996), measuring learning is key to determine which principles, facts, and techniques were understood and absorbed by the trainees. The criteria for observations was to determine if the criteria for learning could be seen. This would be seen in the comprehension of Lean principles being taught as well as the process of experiential learning in the Learning Factory. An example of the detail that went into capturing the observations is shown in Appendix 9.6. This section will summarise the findings from studying both groups that participated in the Learning Factory.

These are described under observation criteria specified in the methodology and presented in Table 5.9.

Table 5.9: Observations from Learning Factory training

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
Ability to relate BI to their environment	Struggled to understand customer in the context of their operation	High awareness of their customers and related to their context and customers often
Ability to identify and differentiate between the types of waste	Waste vs Value was difficult to understand without initial understanding on customer. Differentiated between the different types of waste and could relate this to their work places quite easily as well.	Waste vs Value - work sampling activity data helped them make the connection as they could see the small percentage of Value Adding work. Participants easily identified the eight types of waste during the waste walk in the Learning Factory employees. Appreciated three principles of sustainable BI as they were busy with a technical activity but had not considered the aspect of mindsets and capabilities and impact it has
Are participants able to follow a structured problem solving methodology?	Were able to extend process mapping to their operational problem easily. Initial inclination was to jump to solutions before defining the problem statement. The importance of a well-defined problem statement became clear as they practised.	Process mapping was completed practically by observing the Learning Factory and this was well understood. When the participants responded to the wastes observed in the Learning Factory they easily gave solutions to the perceived problem as typically expected if you do not intentionally do an issue investigation.
Do participants know how to use RCA tools?	Participants could articulate how doing a proper fishbone to identify the root cause could lead to quicker resolution of breakdowns. The Five Why tool was known by all but has not always been used appropriately and effectively.	Only four participants had used RCA tools prior to the training. Key takeaway was that the process boundaries need to be well defined first. With Five Why, the key learning was the importance of asking the right question to get to the root cause and without focus it is easy to digress

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
Ability to manage bias in brainstorming	Participants realised that they needed to have a clearly defined statement as an ambiguous statement could be interpreted differently.	Key learning was that they needed to manage bias caused by rank and other classes especially when it came to voting

5.2 Results of Kirkpatrick Level 3 evaluation of behaviour

According to Kirkpatrick (1996), measuring behaviour is a way of determining how much of the learning has translated to a change in behaviour in the workplace and is also referred to as transfer of training. The measure chosen is that of looking at improved results or performance in the immediate place or line of work. In this case, the group that went on to execute their project tracked performance of that project. This section will present the results from the projects tracked as well as visual observations made by the researcher in this period.

This section includes the following:

- Project results from Group 1 shown in Table 5.10 and Figure 5.11
- Visual observations made by the researcher displayed in Table 5.11

5.2.1 Project results from group 1

While all participants engaged in Business Improvement projects after their training at the Learning Factory, at the time that this report was written, project data from Group 1 was available as the project was in implementation phase already.

This data from Group 1 is shown in Figure 5.11. The project tracking commenced once the project charter had been signed off and the team started implementing the proposed control actions. Statistical Process Control charts (SPC) have been used to illustrate the before and after intervention. Group 1 identified a metric that they needed to track to see if the control actions they proposed would result in an improvement. In their case, they looked at normalised production which they found was unstable with high variation before implementation. Their objective was to improve stability and reduce variation. Both Figure 5.11 and Table 5.10 show that there was a reduction in variation and this reduction was statistically significant. Table 5.10 shows a summary of statistics from the implementation. A t-test shows that the change in production after implementation is significant. Group 2 had not progressed with implementing their project and so no data was available.

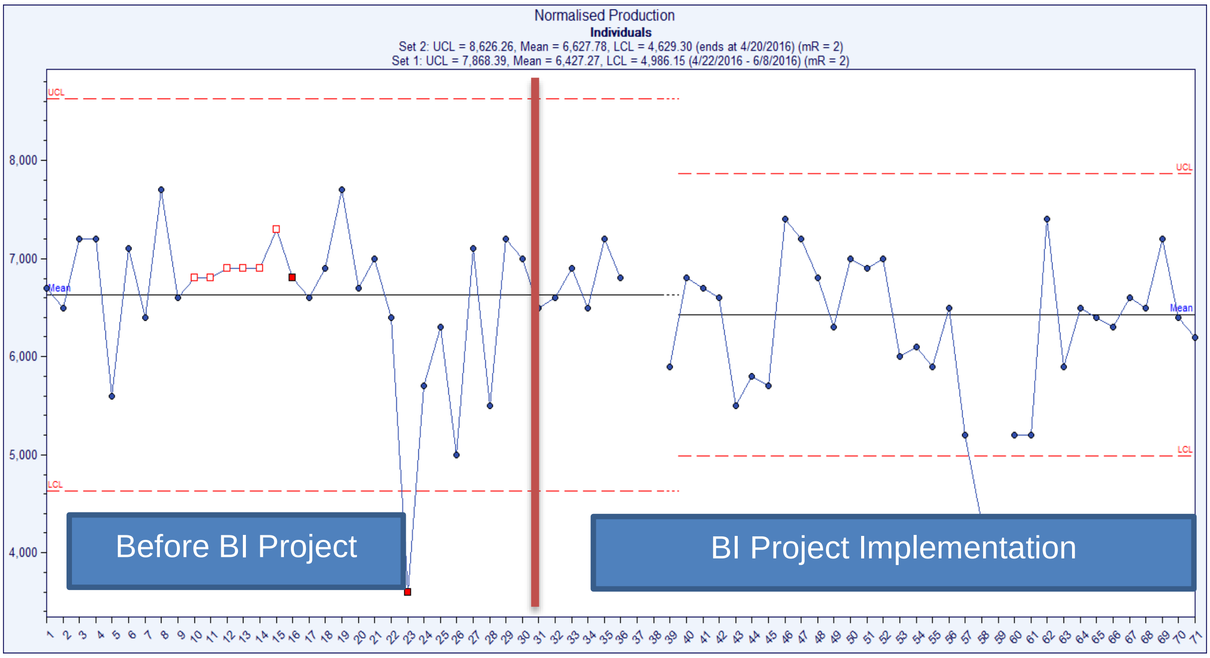

Figure 5.11: Group 1 Case Study Results

Table 5.10: Summary of Group 1 implementation Statistics

	Average Production (tons)	Variance between control limits (tons)	Confidence of T
Before implementation	6627	3997	96.7%
During implementation	6427	2882	

5.2.2 Visual observations on Kirkpatrick Level 3 evaluation of Behaviour

As with section 5.1.7, these observations were made by the researcher serving as a participant observer. For each group, they had to have a project kick-off session where they would launch the project and used the principles from training to structure their project and these observations were noted during those sessions. These findings are summarised in Table 5.11. So while Group 2 had started their project, they had not followed through with implementation.

Table 5.11: Observations from project kick off sessions

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
Are elements of sustainable BI incorporated as teams define their problems?	Only technical systems were considered.	Only technical systems were considered
How easy was it for participants to switch between the types of thinking required in BI?	This was well done as they could easily navigate through the different tools and adjust their thinking	This was well done as they could easily navigate through the different tools and adjust their thinking
Ability to identify and differentiate between the types of waste	Understood both theoretically and practically as participants were able to clearly identify them during their root cause analysis	Concepts of Value vs Waste came out The answers that came out sought to identify where waste was in the process and how the waste was contributing to their problem.
Are participants able to follow a structured problem solving methodology?	They were able to apply the A3 problem solving tool Seen to an effective way of getting all options considered and some senior employees marvelled at how much they had not known about the problem but were able to surface through a structured process	Application of A3 problem solving tool was not done rigorously
Is process mapping applied to their problem?	Done loosely, not able to tie it well to their process. This was in contrast to how they had applied it well initially at the Learning Factory	Initial observation that this activity was well understood in the Learning Factory was confirmed in the project planning sessions as all groups had well-defined macro-maps for their projects

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
Ability to use the Kipling method to define problem statement.	Applied well and this helped the team define their problem	A lot of effort went into defining the problem statement using the Kipling Method and this was well done by all.
Do participants know how to use RCA tools?	The Fishbone Diagram was applied and using this tool helped teams not to jump to solutions as was previously observed at the Learning Factory.	Fishbone diagram was applied
Were participants able to use brainstorming?	Brainstorming energy was high and there was an effective use of post-it notes to collect ideas from all members that was observed	Collective effort observed.

5.3 Summary

This section summarises the results presented in this chapter. The results were presented according to two of the criteria measuring effectiveness of training according to the Kirkpatrick Model. For both these criteria, data was presented and analysed. The statistical significance of the data was presented as well as visual observations made by the researcher.

For measuring the effectiveness of training using the Kirkpatrick Level 2 criteria of Learning, before-and-after tests were used. A summary of this data is presented in Figure 5.12. The before training results of all participants are shown across the different levels of work and across the two groups who participated in the study. These results are shown alongside the after training results. One finding that stands out is that before training, participants are at different starting points for each of the Lean principles however after training, they improve and have a similar end point of understanding.

For measuring the effectiveness of training using the Kirkpatrick Level 3 criteria of Behaviour, project data from the immediate place of work was used. Only Group 1 implementation results were available and these are shown in Figure 5.11. An improvement in the project data being tracked was noted and this difference was shown to be statistically significant.

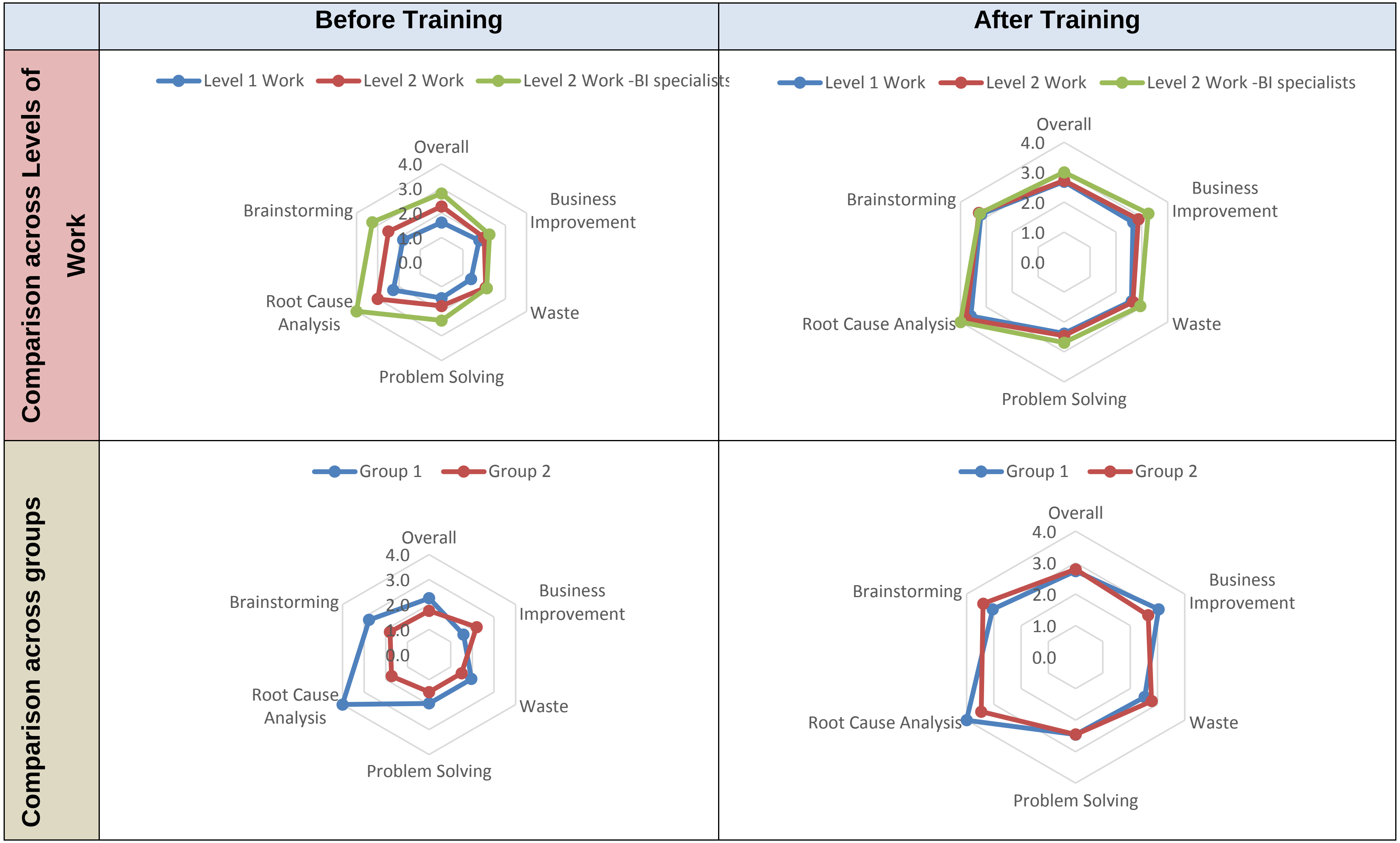

Figure 5.12: Summary of Results

Lastly, visual data was used in both criteria and the sets of observations in Learning and Behaviour shown in Table 5.9 and Table 5.11 are triangulated with the assessment grading.

Observation: Ability to relate Business Improvement to their environment

The findings made in the visual observations in Table 5.9 and Table 5.11 match the grading for Business Improvement where participants were found to have understood the principal. The gap between understood and well understood is evident in the application of sustainable BI principles

Observation: Ability to identify and differentiate between the types of waste?

This visuals observation made are consistent with grading for waste where participants showed that they understood the principle. It was evident that participants knew how to identify and differentiate between the types of waste even for their specific projects

Observation: Are participants able to follow a structured problem solving methodology?

The observation was telling in that Group 2 did not proceed with implementation and the grades obtained by Group 2 in the questionnaires showed that this principal remained partially understood. Group 1 grading showed that the principal remained partially understood, however visual observations showed that they were able to apply it and follow through with implementation in a structured way.

Observation: Do participants know how to use RCA tools?

The findings presented in Table 5.9 and Table 5.11 showed that the Fishbone tool was used and applied by all and this matches the grading obtained in the questionnaires of well understood.

Observation: Ability to manage bias in brainstorming

The observations made by the researcher as participants actively applied the tools are consistent with the grading that participants obtained which showed that the principles were understood.

6 Discussion of Results

Following the results presented in section 5, this section will analyse the results to evaluate how the objectives have been met. This section will consolidate the different sets of data obtained by different methods.

The main objectives of this research are:

- Determine how well the Lean principles are understood after being taught through the Learning factory
- Determine how well they are applied in the workplace after they have been taught
- Determine how well they are understood and applied across hierarchy levels in an organisation

The discussion of the results will be structured according to the objectives.

6.1 Understanding of Lean principles after Learning Factory training

Two groups of participants were trained through the Learning Factory, the first group works at a Mineral Processing Operation while the second work at Operations Services Support. The first part of the results sought to evaluate how well the Lean principles were understood within the groups and across the groups. Figure 5.1 showed that Group 1 employees (Mineral Processing Operation) started at a higher level of understanding of Lean principles prior to the training in the Learning Factory compared to Group 2. Drilling down further to specific Lean Principles in Figure 5.2, the concept of Root Cause Analysis was already well understood while Brainstorming was understood. This high initial understanding for these Lean Principles is expected because a workforce at a mining operation will have to do trouble shooting on equipment or process issues on an ongoing basis as part of the work done. The change in understanding of Lean principles was 21% and using the t-test, this change was found to be statistically insignificant.

Comparing these results to Group 2 in Figure 5.3 from the Operations Services Support, they had a lower starting base in terms of overall understanding of

Lean and the 60% increase in understanding was found to be statistically significant. These Lean principles are not widely used in their day to day work and so this lower starting point was expected.

A similar approach was used by Cachay, et al., (2012) to investigate the effectiveness of Learning Factories compared to conventional lectures. The difference with this research and that of Cachay, et al., (2012) is that there was no comparison to conventional lectures in this research so the analysis of Cachay, et al., (2012) study is only limited to their Learning Factory results. The results from the before training and after training showed that training in the Learning Factory resulted in some participants being able to increase their score by more than 100% (Cachay, et al., 2012). As such, an increase in understanding is expected as shown by both Group 1 and Group 2. As each of the individual Lean principles are discussed in detail next, the increase in understanding is shown and in some cases it exceeds 100%. This is expected because of the effectiveness of the Learning Factory.

6.1.1 Understanding of Lean Principle – Business Improvement

The concept of Business Improvement was introduced to participants as it is a new discipline to mining. The principle of Business Improvement sought to raise awareness on Business Improvement and in particular the elements of sustainable Business Improvement. Results are shown in Table 5.4 and t-test results are shown in Table 5.3.

The concept of Business Improvement as a whole was either not understood or partially understood initially by all employee categories. This is expected as the concept of Business Improvement and Lean is new to this mining organisation and to most of the mining industry at large. Post training, this concept was mostly understood and the significance test showed that the 91% increase in understanding for Group 1 was significant while the 21% change by Group 2 was not significant so this concept made a bigger difference to the Mineral Services Operation group. This is confirmed by the observations were Group 2 had a higher awareness of the customer in the initial discussions on Business Improvement. This is consistent with the work they do in providing a service to the customer. Group 1 on the other hand battled to identify customers as subsequent downstream processes within the operation as they are used to looking at the operation as a whole and only consider customers external to the operation. This understanding is key as observed by Wijaya, et al. (2009), who refer to the starting point for Lean application as being understanding value based on the customer's need and so identifying the correct customer is essential.

As the groups practised the subsequent principles in different examples, they were able to identify how the three elements of sustainable Business Improvement were interconnected. An example is when both groups undertook a waste walk; they focused on the technical systems aspect of BI and realised that they were ineffective as they had not considered the mindsets and capabilities aspect. Through application they cemented their understanding of this principle.

6.1.2 Understanding of Lean Principle – Waste

The Lean Principle of Waste was identified to be one of the foundation Lean principles that the mining workforce would need to know and be able to apply. The participants were trained on the Lean principle of waste and they were taken through defining and identifying waste, value as well as the sources of waste. Results are shown in Table 5.5 and t-test results are shown in Table 5.3.

This principle was either not understood or partially understood by all employee groups before training. The t-test results showed that the change in understanding of 96% and 86% for Group 1 and Group 2 respectively is statistically significant. Post training, all groups advanced to understanding the concept. Observations showed that participants grappled with this content in the classroom and had rich discussions when it came to relating to value in the eyes of the customer. The waste walk showed that they were able to identify the different types of work but struggled with differentiating between value-adding work and non-value adding work until they did a practical exercise that deepened their understanding. Without fully understanding the concept of customer defined in the Business Improvement principle, it is hard to relate to the concept of waste. This is evident from Group 1 where most of the group remained with a partial understanding. Further, this concept of waste was identified as a fundamental Lean tool that was applied at most of the mining operations that have already implemented Lean as shown in Table 2.1. This is because the practices of waste are not limited by the mining environment itself and can be easily extended to add value to the business. This is also highlighted by Loow (2015) who considered 17 Lean implementations in mining and found that waste was the most applied principle. It would be worthwhile to consider how this principle can be understood even further.

6.1.3 Understanding of Lean Principle – Root Cause Analysis

The Lean principle of Root Cause Analysis was presented to the participants through the Learning Factory. Participants were trained to identify root causes using tools such as Five why and Fishbone diagram. Results are shown in Table 5.6 and t-test results are shown in Table 5.3.

The groups had vastly different initial starting points. This concept was well understood by Group 1 prior to the training and this understanding was sustained even after the training. As such, the t-test could not be used to measure the significance of the change in understanding as none was observed. This is expected as this workforce is involved in identifying problems on machinery or the process as part of their work and would rely on RCA tools to assist them. Group 2 on the other hand started with either no understanding or partial understanding however this changed to either understood or well understood for all employee categories. The significance testing shows that the 100% increase in understanding is significant statistically.

Observations showed that both groups were able to apply the tools in the classroom setting and practically on the Learning factory.

6.1.4 Understanding of Lean Principle – Brainstorming

Brainstorming as a Lean concept was presented to participants. Participants needed to understand brainstorming and its benefits as well as apply it. This principle is found under the creative involvement of workforce in the Lean framework adopted in this study. It aims to create a culture of process improvement into the minds of the workforce and facilitate team based responses. Results are shown in Table 5.7 and t-test results are shown in Table 5.3.

This concept was partially understood by all employees with the exception of the BI specialists who already understood it prior to training. Post training, this concept was now understood by all employees save for the supervisors who achieved well understood. Significance testing showed that the 10% change in understanding by Group 1 employees is not statistically significant while the 88% change by Group 2 is.

The observations showed that for one to effectively brainstorm they needed to have a well-defined problem statement to guide them and this shows the interconnected nature of these principles as described by (Lyons, et al., 2011). Through application, they were able to experience some of the pitfalls of brainstorming such as influence of rank that brings bias.

6.1.5 Understanding of Lean Principle – Problem Solving

The participants were exposed to the concept of Problem Solving as a foundation Lean principle in the Learning Factory. The participants were assessed on their understanding of problem solving by looking at how to define a problem statement, using a structured problem solving procedure and importance of validating root causes. Results are shown in Table 5.8 and t-test results are shown in Table 5.3.

Participants started off with either no understanding or partial understanding of this principle. The t-test showed that the 26% and 63% increase in understanding by Group 1 and Group 2 respectively is statistically significant. Although there was an increase in understanding, most participants remained with only a partial understanding of this principle except for Level 2- BI Specialists who understood the principle.

This finding is confirmed by the observations. Participants were inclined to jump to solutions before fully defining the problem. This is probably something they have been doing as they do their work so instilling the discipline of carefully defining the problem statement was a new concept to them. Defining a problem statement seemed easy at first glance as they followed the Kipling method but it became clear that how the questions were asked was significant to the quality of problem statement achieved. With this process, they had to establish process maps to understand the boundaries of the problem and process within and this was well understood by both groups.

Of all the Lean principles studied, this principle showed the lowest understanding level after training. However, the experience in application was different as the groups followed a structured way of Problem Solving which incorporated all they had learnt. This was done well and the groups showed that the concept had been understood at application level.

6.2 Understanding of Lean principles across hierarchy levels

This study also sought to determine the understanding of Lean principles across hierarchy levels and the employment levels were classified using the Levels of Work Model. For this study there were three employee levels namely those who engage in Level 1 Work, Level 2 Work and Level 2 Work BI Specialists. The results are presented in section 5.1.6.

Employees participating in Level 1 work include Artisans, Processors, Administrators and Supervisors. For employees involved in Level 1 work, they either did not understand or partially understood all the Lean principles prior to training as shown in Figure 5.8. After training, their understanding of all Lean principles improved and the change ranged from 50% to 88%. The grades obtained showed that they now understood the Lean Principles with Root Cause Analysis being well understood. The exception was the Problem Solving principle which only improved to that of partial understanding. The Lean principle of Waste showed the biggest improvement in understanding among Level 1 work employees while Root Cause Analysis was well understood

Level 2 work employees that participated in this study include Engineering Managers, Production Managers and Analysts and their results are shown in Figure 5.9. With the exception of Root Cause Analysis which was already understood before training, all principles were partially understood. None of the principles were not understood at all which shows a higher starting point compared to Level 1 work employees. When it comes to understanding of principles after training, a similar trend to Level 1 work employees is shown whereby all principles are now understood with Root Cause analysis being well understood, however Problem solving remains partially understood. While the change in understanding is greater for Level 1 work employees (50% - 88%), Level 2 work employees' understanding increased by between 20% and 43%. The Lean principles of Business Improvement and Problem Solving showed the biggest upgrading in understanding among Level 2 work employees while Root Cause Analysis was well understood.

Results for Level 2 work employees who are BI specialists are shown in Figure 5.10. The concepts of Brainstorming and Root Cause Analysis were already understood and well understood respectively preceding the training. The rest of the principles were partially understood. When it comes to understanding of principles after training, a different trend to Level 1 work and Level 2 work employees is shown as all principles are now understood with Root Cause analysis being well understood. Even the concept of Problem Solving is understood by these participants. This group however shows the smallest change in improvement compared to the participants in the other employment levels as a change of between 0% and 44% is observed. The Lean principles of Business Improvement and Waste showed the biggest progression in understanding among the Level 2 work BI Specialists while Root Cause Analysis was well understood.

The results showed that all three employee groups showed an increase in overall understanding of Lean after training in the Learning Factory with the biggest change of 67% shown by Level 1 Work employees as shown in Figure 5.7. As expected, the BI specialists already understood Lean principles before exposure to the Learning Factory and their grading demonstrated a slight increase in understanding after the Learning Factory. For the other employees, they showed partial understanding of Lean concepts prior to training and their overall understanding improved to that of understanding Lean concepts.

Interestingly, all employee groups demonstrated that the Lean principles have been understood after training with a similar score between 2.7 and 3.0. This is momentous as it means that the Level 1 Work employees who started with partial understanding were able to boost their understanding of these principles to be in the same range as the Level 2 Work BI Specialists. The BI specialists are trained for extended period of time in this area and also practice the principles in the course of their work. This significant gain in understanding was achieved in much shorter period of time. This confirms what Abele, et al. (2015) established about Learning Factories being a tool that can develop employee competencies fast to match the fast-changing market conditions. In their study, Abele, et al. (2015) found that Learning Factories promote the development of participants' ability to master complex unfamiliar situations. As mentioned earlier in this study, Lean principles are new to this workforce and present an unfamiliar situation, however through the Learning Factory, even the Level 1 work employees have been able to master this concept. A similar trend is observed for the Level 2 work employees who start with partial understanding though they have a higher understanding than Level 1 Work employees. After training, they all understand the concepts at the same level as Level 2 Work BI specialists.

This versatility of the Learning Factory in developing employees across all hierarchical levels will be beneficial to the mining industry at large as it rapidly seeks to facilitate the application of newly acquired skills and competencies and this was also observed by Abele, et al. (2015).

6.3 Application of Lean principles in the workplace

The participants went on to apply the Lean principles in their respective workplaces after training in the Learning Factory. They did this by identifying Business Improvement projects they needed to work on and initiated the projects at Project Kick-off. The researcher was able to observe the project kick-off sessions and from there identify how well the Lean Principles were applied in the workplace. Group 1 had started implementing their project at the time the report was compiled and that early data has been included as part of the results. The results are shown in section 5.2.

The intersected nature of these principles as described by Lyons, et al (2011) becomes more apparent during the application of the Lean Principles. Slack & Michael (2011) also highlight that while the principles are distinct, they are mutually supportive and when they mesh together they form the Lean approach.

In working on their projects, groups spent time defining their problem statements using problem solving tools. They had the A3 problem solving template and that gave the teams a consistent approach they could follow. The Kipling method for defining a problem statement was well applied as most groups managed to come up with a well-defined problem statement which helped them to explain and clarify their scopes. The use of process mapping was applied well by Group 2 in defining their project boundaries while this was not done well by Group 1. In this step, the convergent principles that are required in defining a problem were well applied.

The next step was to determine the root cause using Root Cause Analysis tools and Brainstorming. All groups chose the Fishbone diagram to determine the root causes and they used a lot of brainstorming techniques to establish the root causes. Once again the interconnectedness of the principles was observed as the answers that came out were guided by identifying the different forms of waste that were resulting in non-value adding work. This was in addition to their technical understanding of the situation. As such, some senior employees were amazed at how they considered more options than they would have normally done from a technical perspective alone and even understood the problem better.

This ability to apply learning after exposure to the Learning factory is expected based on the study done by Cachay, et al, (2012) which showed that students have a greater application performance after being taught in a Learning Factory compared to a conventional lecture. Training through a Learning Factory results in a higher degree of action-substantiating knowledge that results in application of principles.

What was not observed in application was the application of sustainable BI as both teams only focused on technical systems and no consideration was given for other aspects like mindsets and capabilities during this process. This is a common pitfall that has been observed in other Lean implementations where the focus is on the tools primarily with little or no regard for the enabling culture required to sustain the implementation as highlighted by Castillo, et al. (2014). They highlight that Lean implementations result in cultural change to the way that things have been done before and so this focus on mindsets and capabilities is important. This point is also raised by Sanda, et al. (2011) who stress that for Lean to be successfully implemented there needs to be emphasis on development of the appropriate mining culture. In the broader sense, Panneman (2016) highlights that most companies that invest in the tools that facilitate a Lean outcome (Process) and neglect the other three principles (Philosophy, People and Partners, Problem Solving) from the Toyota Production System have a higher chance of a failed implementation.

Statistical Process Control charts (SPC) have been used to illustrate the before and after intervention. With project implementation still ongoing the project data from Group 1's implementation shows a reduced variation in the normalised production. This demonstrates a more stable process and with stability comes better predictability. While the mean has shifted downwards in the more stable process after the implementation of the control actions, the production is still within the specifications and is now being achieved in a more predictable manner. This is consistent with Yingling, et al (2000) who highlight that stability is achieved through Lean implementations and so this result is expected. Improved stability was also identified as one of the benefits of Lean implementation in section 2.3.1 which leads to predictable performance (Dassault Systemes, 2015).

There was no implementation data for Group 2 due to the lack of traction in their implementation. So while the participants were trained and had initiated the project during project kick-off there was a lack of momentum to see the project through. While this was disappointing to the researcher, further investigation showed that there was no urgency for the implementation and that the implementation projects were not seen to be a priority by the line management. This is a key finding that confirms that management buy-in is a key success factor for Lean implementations. In the literature review, three main success factors were identified and the Learning Factory sought to close the gap on previous experience and training. So while Group 2 was trained, without the other success factor of management buy-in, the application of this training was limited.

This interrelated nature of the success factors and how they relate to the ADKAR change management was investigated in the literature review. It was found that to get management buy-in, work on building awareness and desire to change is required. Putting this effort upfront could better serve the training and improve the capability building through the Learning Factory.

7 Conclusion and Recommendations

This section seeks to summarise the conclusions reached in this study.

7.1 Research conclusion

The purpose of this study was to answer this key research problem:

Is the Learning Factory an effective way of imparting Lean principles to develop Business Improvement capability in mining employees?

This research has found that the Learning Factory is effective in imparting Lean principles and methods to mining employees. This is demonstrated by the increase in understanding post training in the Learning Factory and the ability to apply the learnings in their respective workplaces after they have been taught. Understanding and the ability to apply the understanding lead to capability.

In addressing this problem, the following research questions were presented:

1. Is the Learning factory an effective way in imparting Lean principles and methods to mining employees?
2. How effective is the Learning factory in imparting these skills across different hierarchy levels in a mining operation?

This research has found that the Learning Factory is effective in imparting the Lean skills across hierarchy levels in a mining operation. Level 1 Work employees with very little knowledge of Lean ended up understanding it to the same level as Level 2 Work BI Specialists who are trained extensively in this subject. Further, all employees arrived at the same overall understanding post training regardless of their starting point.

7.2 Summary of research findings

<u>Finding one</u>: different participants in the Learning Factory had substantially different starting points in terms of understanding based on their employment level as well as the nature of the work they do. It was found that employees from the Mineral Processing Operation had a higher starting point due to certain aspects of Lean manifesting in their day to day work compared to the

Operations Services Support group. This second group however had a better understanding of the concept of customer which allowed them to rapidly understand the Lean principles.

Finding two: there was an increase in understanding of Lean principles after being taught through the Learning Factory and this applied across all Lean principles taught across all groups.

Finding three: the participants were able to apply most of the Lean principles in the workplace through the Business Improvement projects they were working on. What was a concern was that the main focus was on technical systems with little regard for other aspects that contribute to sustainable Business Improvement such as mindsets and capabilities.

Finding four: this study also found that Lean principles taught through the Learning Factory resulted in an increase in understanding and application across all hierarchy levels. All employee groups had similar level of understanding post training. This includes the Level 1 Work employees who started with the lowest understanding of Lean and were at similar understanding with Level 2 Work BI Specialists post training.

Finding five: while the Learning Factory can assist in building capability, the other success factors to Lean implementations can either enhance or impede this effort as was seen by the low management buy-in faced by group 2 participants

7.3 Contribution to practice

The results of this study demonstrate that Learning Factories can be used to rapidly build capability in Lean principles in mining workforces. This is significant as the mining industry seeks to increase efficiency and strive for massive operational performance improvements as experienced by the manufacturing industry after adopting Lean principles (Nyamarebvu, 2012). In order to achieve successful and sustainable Lean implementations, they need to focus on building capability to ensure employees are competent and can apply Lean methods efficiently. More mining companies should consider investing in this type of learning tool particularly to support their drive to be Lean. This study has shown that the Learning Factory has been able to do rapidly provide knowledge and ability on Lean as prescribed by the ADKAR change model.

7.4 Recommendations

Based on this study, the following is recommended

- Evaluation of the current Learning Factory curriculum used for training to cater for employees coming from different work environments to ensure it is appropriate for the different starting points observed
- Consider training the participants involved in this study on the outstanding foundation Lean principles and evaluate if there is increased and deeper application of Lean in their workplaces with the full suite
- Consider doing a study to determine the interrelated nature of the factors that drive a successful Lean implementation and the extent that a change management program like ADKAR can be used to maximise success

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9 Appendix

9.1 Questionnaires

9.1.1 Group 1

Lean Questionnaire – Before Training

Please mark appropriate box

Place of work	Mine		Plant		Support offices	
Current position						
Engineering	Artisan		Artisan assistant		Section engineer, specialist	
Processing	Processor, Supervisor		Shift Leader/ Foreman		Day shift leader/ Metallurgist	
Business Improvement	BI Specialist		BI Principal			
Other						

1. What is your understanding of Business Improvement?

2. What is the definition of a waste?

3. What is the importance of having a structured problem solving procedure in place when faced with a problem?

4. Name one tool used to determine root causes?

5. What is the benefit of brainstorming?

Lean Questionnaire – After Training

Please mark appropriate box

Place of work	Mine		Plant		Support offices	
Current position						
Engineering	Artisan		Artisan assistant		Section engineer, specialist	
Processing	Processor, Supervisor		Shift Leader/ Foreman		Day shift leader/ Metallurgist	
Business Improvement	BI Specialist		BI Principal			
Other						

1. What is your understanding of Business Improvement?
2. What are the three types of work?
3. What is the definition of a waste?
4. Why is it important to identify and eliminate all wastes in the process?
5. Name any four of the commonly observed sources of waste.
6. What statements/tools would you consider when coming up with a problem statement to define a problem?
7. What is the importance of having a structured problem solving procedure in place to determine root causes?
8. Name one tool used to determine root causes?
9. What is the benefit of brainstorming?
10. Why is it important to validate root causes?
11. Why is it important to validate potential control actions?

9.1.2 Group 2

Lean Questionnaire – Before Training

Please mark appropriate box

Place of work						
Current position						
	Administrator		Supervisor		Analyst	
Other						

1. What is your understanding of Business Improvement?

2. What is the definition of a waste?

3. What is the importance of having a structured problem solving procedure in place when faced with a problem?

4. Name one tool used to determine root causes?

5. What is the benefit of brainstorming?

Lean Questionnaire – After Training

Please mark appropriate box

Place of work						
Current position						
	Administrator		Supervisor		Analyst	
Other						

1. What is your understanding of Business Improvement?
2. Give any one of the three elements of Sustainable Business Improvement.
3. What is the difference between value add vs non-value add work?
4. What is the definition of a waste?
5. Why is it important to identify and eliminate all wastes in the process?
6. Name any four of the commonly observed sources of waste.
7. Give any two questions/statements you would consider when coming up with a problem statement to define a problem?
8. What is the importance of having a structured problem solving procedure in place when addressing a problem?
9. Name one tool used to determine root causes?
10. What is the benefit of brainstorming?
11. Why is it important to validate causes?

9.2 Questionnaire grading results

Table 9.1: Questionnaire grading results for both groups

Group 1 - Mineral Processing Operation																			
	Before							After											
	Business Improvement	Waste	Problem Solving	Root Cause Analysis	Brainstorming			Business Improvement	Waste				Problem Solving				Root Cause Analysis	Brainstorming	
Question	1	2	3	4	5	Ave		1	2	3	4	5	6	7	11	10	8	9	Ave
Artisan	1.0	1.5	1.5	4.0	2.0	**2.0**		4.0	1.0	3.0	2.5	4.0	4.0	2.5	1.0	3.5	4.0	3.0	3.0
Artisan	1.0	1.5	1.0	4.0	2.0	**1.9**		4.0	1.0	1.5	2.0	4.0	1.0	1.0	1.0	4.0	4.0	2.5	2.4
Artisan								3.0	1.0	2.0	1.0	4.0	4.0	2.5	1.0	2.5	4.0	2.5	2.5
Artisan	1.0	1.5	2.0	4.0	2.0	**2.1**		1.0	4.0	1.0	2.0	4.0	4.0	1.0	3.0	4.0	4.0	3.0	2.8
Processor/Supervisor	1.0	2.0	2.0	4.0	2.0	**2.2**		3.0	1.0	3.0	1.0	4.0	1.5	1.0	3.5	3.5	4.0	2.0	2.5
Section Eng/ Specialist	2.0	1.5	1.5	4.0	3.0	**2.4**		3.0	1.0	3.0	1.0	4.0	1.0	3.0	1.0	3.5	4.0	4.0	2.6
Day shift leader/ Metallurgist	1.5	4.0	2.0	4.0	3.0	**2.9**		2.5	1.0	1.5	1.0	3.5	1.0	1.0	3.5	1.0	4.0	3.0	2.1
Day shift leader/ Metallurgist	1.0	1.0	2.0	4.0	3.5	**2.3**		3.0	1.0	3.0	3.5	4.0	1.0	2.5	3.5	3.5	4.0	3.5	3.0
BI Intern	4.0	3.0	4.0	4.0	3.0	**3.6**		4.0	1.0	4.0	3.0	4.0	1.0	3.0	1.0	1.0	4.0	3.5	2.7
BI Specialist	2.0	2.0	2.0	4.0	3.0	**2.6**		3.0	1.0	2.0	2.0	4.0	4.0	3.0	3.0	3.5	4.0	3.0	3.0
BI Specialist	1.5	2.5	1.5	4.0	4.0	**2.7**		4.0	3.0	4.0	3.0	4.0	3.0	3.0	3.0	3.0	4.0	3.0	3.4
BI Specialist	1.5	1.0	2.0	4.0	3.0	**2.3**		2.0	4.0	3.0	1.0	4.0	4.0	2.5	4.0	1.0	4.0	3.5	3.0
Group 2 - Operations Support Services																			
	Before							After											
	Business Improvement	Waste	Problem Solving	Root Cause Analysis	Brainstorming			Business Improvement		Waste				Problem Solving			Root Cause Analysis	Brainstorming	
Question	1	2	3	4	5	Ave		1	2	3	4	5	6	7	8	11	9	10	Ave
Adminstrator	2.0	1.5	2.0	1.0	2.5	**1.8**		2.0	4.0	3.0	2.0	3.0	4.0	4.0	1.0	2.0	4.0	4.0	**3.0**
Adminstrator	1.0	1.0	1.0	1.0	1.0	**1.0**		1.0	4.0	2.5	3.0	1.5	4.0	4.0	1.5	2.0	4.0	1.0	**2.6**
Adminstrator	1.0	1.5	1.0	1.0	2.5	**1.4**		4.0	4.0	3.5	3.0	1.5	4.0	4.0	1.0	2.0	1.0	4.0	**2.9**
Adminstrator	3.0	1.0	2.0	1.5	1.0	**1.7**		3.0	4.0	2.5	3.0	1.5	1.0	4.0	1.5	1.5	4.0	2.5	**2.6**
Adminstrator	1.5	1.0	1.5	1.5	1.0	**1.3**		1.0	1.0	4.0	2.0	1.5	4.0	1.0	1.5	3.0	4.0	4.0	**2.5**
Adminstrator	3.5	1.5	1.0	1.5	1.0	**1.7**		3.0	4.0	2.5	3.0	2.0	4.0	4.0	2.0	2.0	4.0	4.0	**3.1**
Adminstrator								1.0	1.0	3.0	3.0	1.0	1.0	1.0	1.0	3.0	1.0	4.0	**1.8**
Supervisor	3.0	2.0	1.5	4.0	3.0	**2.7**		3.0	2.0	3.0	3.0	2.0	3.0	4.0	1.5	2.0	4.0	3.5	**2.8**
Supervisor	1.5	1.0	1.5	1.0	2.0	**1.4**		3.0	1.0	4.0	3.0	1.0	4.0	4.0	1.5	2.0	4.0	4.0	**2.9**
Supervisor	2.5	1.0	1.0	1.0	1.5	**1.4**		1.5	4.0	3.5	3.0	1.5	4.0	4.0	1.5	2.0	4.0	4.0	**3.0**
Analyst	2.5	1.5	1.5	1.5	3.0	**2.0**		2.0	4.0	3.0	3.0	1.5	4.0	1.0	4.0	2.0	4.0	4.0	**3.0**
Analyst	2.5	3.0	3.0	4.0	2.0	**2.9**		3.0	1.0	3.5	3.0	1.0	4.0	4.0	2.5	3.5	2.5	4.0	**2.9**
Analyst	3.0	2.0	1.5	1.0	1.5	**1.8**		3.0	4.0	3.0	3.0	2.0	4.0	4.0	1.5	1.5	4.0	3.0	**3.0**
Analyst	1.5	1.5	1.0	2.5	1.5	**1.6**		3.0	3.0	4.0	3.0	2.0	3.0	4.0	1.5	4.0	4.0	1.5	**3.0**

9.3 Moderated Questionnaires

GSS 2

BB12

Moderation

9,5

Lean Questionnaire

9

Please mark appropriate box

Place of work	Anglo American Global Shared Services				
		Current position			
	Administrator		Supervisor		Analyst	✓
Other					

1. What is your understanding of Business Improvement?

2,5 To Understand all prosesses and to Improve or close the Gap by analysising and the problem/issues in such a manner that is effective, efficient and substainible. 3,0

2. What is the definition of a waste?

1,5 A waste is something that is unnesseray for a proses to continue. 2,0

3. What is the importance of having a structured problem solving procedure in place when faced with a problem?

1,5 To ensure you do not miss any important part of the proses. To ensure and understand where and how you should solve it. 1,5

4. Name one tool used to determine root causes?

1,0 Analysing the process for efficiency. 1,0

5. What is the benefit of brainstorming?

3,0 Getting a different view of a diversed group of people who have different ways of thinking & interepreting. 1,5

As a pre-question, this answer deserves a higher score. Pulling together a diverse group is definitely a benefit

GSS 1

AA10

Moderation

31,5

Lean Questionnaire

33

Please mark appropriate box

Place of work						
			Current position			
	Administrator	X	Supervisor		Analyst	
Other						

1. What is your understanding of Business Improvement? 2,0

2,0 Its a workshop that teaches you how to define problems within an organisation so that you can improve process that arent working or better those that are.

2. Give any one of the three elements of Sustainable Business Improvement.

4,0 Technical Processes
Management Infrastructure 4.0
Mindset & Capabilities

3. What is the difference between value add vs non-value add work?

3,0 Value - Work that the customer is willing to pay for. Transforms the product. 3,0
Non-Value: Work that adds no value to the customer.

4. What is the definition of a waste?

2,0 waste can be defined as all the factors in a process that add no value ~~and~~ to the customer and sets the organisation back 2,0

5. Why is it important to identify and eliminate all wastes in the process?

2,0 To eliminate non-value work that makes no difference to the customer. 3,0

6. Name any four of the commonly observed sources of waste.

Waiting
Talent
4,0 Overproduction. 4.0
Motion.

AA10/2

Moderation

7. Give any two questions/statements you would consider when coming up with a problem statement to define a problem?

4,0 When did this become a problem
What is the problem. 4.0

8. What is the importance of having a structured problem solving procedure in place when addressing a problem?

1,5 So that the problem can be defined properly, and so that it is simpler to validate the data collected. 1.0

9. Name one tool used to determine root causes?

4,0 5. Why's. A.0

10. What is the benefit of brainstorming?

3,5 It allows for more ideas to be shared. and helps broaden the understanding of the problem A.0

11. Why is it important to validate causes?

1,5 So that one can see if that ~~is the actual~~ it is not a common cause, also to change opinions to facts 2,0

AA10/2

Moderation

7. Give any two questions/statements you would consider when coming up with a problem statement to define a problem?

4,0 When did this become a problem
What is the problem. 4.0

8. What is the importance of having a structured problem solving procedure in place when addressing a problem?

1,5 So that the problem can be defined properly, and so that it is simpler to validate the data collected. 1.0

9. Name one tool used to determine root causes?

4,0 5. Why's. 4.0

10. What is the benefit of brainstorming?

3,5 It allows for more ideas to be shared and helps broaden the understanding of the problem 4.0

11. Why is it important to validate causes?

1,5 So that one can see if that ~~is the actual~~ it is not a common cause, also to change opinions to facts 2,0

Ops2

B2

11/03/2016
MSC ICC

Moderation
26,5

Lean Questionnaire

26

Please mark appropriate box

Place of work	Mine		Plant		Support offices	
			Current position			
Engineering	Artisan	✓	Artisan assistant		Section engineer, specialist	
Processing	Processor, Supervisor		Shift Leader/ Foreman		Day shift leader/ Metallurgist	
Business Improvement	BI Specialist		BI Principal			
Other						

1. What is your understanding of Business Improvement? or system
4,0 – Is a structured approach to improve the value of the business for all stakeholder & investors. 4

2. What are the three types of work?
– Techical system
1,0 – Mindset & Capability 1
– Management infrastructure.

3. What is the definition of a waste?
1,5 – is the time spent not doing the specific or direct tasks, whilst we move around looking for spares. 1,5

4. Why is it important to identify and eliminate all wastes in the process?
2,0 – In order to reach the target to fullfill the customers order. 2,0

5. Name any four of the commonly observed sources of waste.
– waiting
4,0 – motion 4
– transportation and Inventory.

6. What statements/tools would you consider when coming up with a problem statement to define a problem?
1,0 – fishbone tool. 1

Moderated

7. What is the importance of having a structured problem solving procedure in place to determine root causes?

~~1,5~~ 2,0 - To avoid the repeats and meet our production targets. 1

8. Name one tool used to determine root causes?

4,0 - Fishbone. 4

9. What is the benefit of brainstorming?

2,0 - its the information sharing and searching for the problem solving root 2,5

10. Why is it important to validate root causes?

4,0 - To ensure that the root cause analysis is of good effect to avoid repeats. 4

11. Why is it important to validate potential control actions?

1,0 - To ensure that the time is eliminated from all the waste. 1

9.4 Ethical clearance documentation

9.4.1 Company letter of consent

University of Witwatersrand
School of Mechanical, Industrial & Aeronautical Engineering
1 Jan Smuts Avenue
Braamfontein
Johannesburg
2000

18 March 2016

To whom it may concern

Consent to use [illegible], facilities for case study research

I, [illegible], hereby give Sarah Makumbe (ID: [illegible]) consent to gather data from participants at the [illegible]. and permission to use the data to complete her Master's Research Report

The data gathered will form part of her MSc Research Report titled; '***The effectiveness of using Learning factories to impart Lean principles to develop Business Improvement Skills in mining employees.***'

Anonymity regarding company name and employees as well as confidentiality of information gathered will be assured and respected. The data will be gathered in 2016.

Yours faithfully,

9.4.2 Participant letter of consent

SCHOOL OF MECHANICAL, INDUSTRIAL & AERONAUTICAL ENGINEERING

Letter of Consent – Group-Administered Questionnaires

I, ________________________________, agree to participate in the MSc research entitled **The effectiveness of using Learning factories to impart Lean principles to develop Business Improvement Skills in mining employees** to be undertaken by Sarah Makumbe under the supervision of Teresa Hattingh, and certify that I have received a copy of this letter of consent.

I acknowledge that the research has been explained to me and I understand what it entails, as follows:

1. I will complete two questionnaires, one before training and one after training
2. Each questionnaire is expected to last between 15 – 25 minutes.
3. I have the right to withdraw my assistance from this project at any time without penalty, even after signing the letter of consent.
4. I have the right to refuse to answer one or more of the questions without penalty and may continue to be a part of the study.
5. I may request a report summary, which will come as a result of this study.
6. I am entirely free to discuss issues and will not be in any way coerced into providing information that is confidential or of a sensitive nature.
7. I am not required to provide my name or anything that identifies me.
8. All information gathered is for research purposes only and will be kept confidential.
9. This project was approved by the Faculty of Engineering and the Built Environment of the University of the Witwatersrand and the School of Mechanical, Industrial and Aeronautical Research Ethics Committee (non-medical) of the University.
10. If I have any questions or concerns about my rights or treatment as a participant, I may contact the Chair of the School of Mechanical, Industrial and Aeronautical Research Ethics Committee (non-medical) at 011 717 7343 or by email: Bruno Emwanu Bruno.Emwanu@wits.ac.za

Signed: ________________________________

Date: ________________________________

Thank you for taking the time to assist with this research project. Should you require any additional information regarding the study or completion of the questionnaire, please do not hesitate to ask.

Researcher
Sarah Makumbe
Phone
Email:

Supervisor
Teresa Hattingh
Phone:
Email:

9.4.3 Ethical clearance certificate

Fri 4/15/2016 4:44 PM

Bruno Emwanu <Bruno.Emwanu@wits.ac.za>

Makumbe Ruramai Sarah ethics clearance number

To Makumbe, Sarah

Cc Teresa Hattingh

You forwarded this message on 4/18/2016 10:44 AM.

Dear Ruramai,

I am pleased to inform you that the School Ethics Clearance Committee has completed assessing your application and it has been successfully cleared. The ethics clearance number is MIAEC 008/16. Please use this our reference for all future correspondence on this matter.

By copy of this email your supervisor is also informed.

Regards,
Dr. Emwanu

9.5 Analysis of data

9.5.1 f-test and t-test calculation

Group 1 Statistical Analysis																	
	Overall - MSC			BI MSC			Waste MSC			Problem Solving			RCA			Brainstorming	
	After	Before		After	Before		After	Before		After	Before		After	Before		After	Before
Artisan	3.0	2.0		4.0	1.0		2.6	1.5		2.8	1.5		4.0	4.0		3.0	2.0
Artisan	2.4	1.9		4.0	1.0		2.1	1.5		1.8	1.0		4.0	4.0		2.5	2.0
Artisan	2.5			3.0			2.0			2.5			4.0			2.5	
Artisan	2.8	2.1		1.0	1.0		2.8	1.5		3.0	2.0		4.0	4.0		3.0	2.0
Processor/Supervisor	2.5	2.2		3.0	1.0		2.3	2.0		2.4	2.0		4.0	4.0		2.0	2.0
Section Eng/ Specialist	2.6	2.4		3.0	2.0		2.3	1.5		2.1	1.5		4.0	4.0		4.0	3.0
Day shift leader/ Metallurgist	2.1	2.9		2.5	1.5		1.8	4.0		1.6	2.0		4.0	4.0		3.0	3.0
Day shift leader/ Metallurgist	3.0	2.3		3.0	1.0		2.9	1.0		2.6	2.0		4.0	4.0		3.5	3.5
BI Intern	2.7	3.6		4.0	4.0		3.0	3.0		1.5	4.0		4.0	4.0		3.5	3.0
BI Specialist	3.0	2.6		3.0	2.0		2.3	2.0		3.4	2.0		4.0	4.0		3.0	3.0
BI Specialist	3.4	2.7		4.0	1.5		3.5	2.5		3.0	1.5		4.0	4.0		3.0	4.0
BI Specialist	3.0	2.3		2.0	1.5		3.0	1.0		2.9	2.0		4.0	4.0		3.5	3.0
Average	2.7	2.5		3.0	1.6		2.5	2.0		2.5	2.0		4.0	4.0		3.0	2.8
n	12.0	11.0		12.0	11.0		12.0	11.0		12.0	11.0		12.0	11.0		12.0	11.0
s^2	0.1	0.2		0.8	0.8		0.3	0.8		0.4	0.6		0.0	0.0		0.3	0.5
F		0.5			1.1			0.3			0.6						0.6
Ftest		14%			53%			4%			23%			0%			23%
Ttest		94%			100%			96%			96%						85%
Significance of T		No			Yes			Yes			Yes						No

Group 2 Statistical Analysis																	
	Overall - MSC			BI GSS			Waste GSS			Problem Solving			RCA			Brainstorming	
	After	Before		After	Before		After	Before		After	Before		After	Before		After	Before
Adminstrator	3.0	1.8		3.0	2.0		3.0	1.5		2.3	2.0		4.0	1.0		4.0	2.5
Adminstrator	2.6	1.0		2.5	1.0		2.8	1.0		2.5	1.0		4.0	1.0		1.0	1.0
Adminstrator	2.9	1.4		4.0	1.0		3.0	1.5		2.3	1.0		1.0	1.0		4.0	2.5
Adminstrator	2.6	1.7		3.5	3.0		2.0	1.0		2.3	2.0		4.0	1.5		2.5	1.0
Adminstrator	2.5	1.3		1.0	1.5		2.9	1.0		1.8	1.5		4.0	1.5		4.0	1.0
Adminstrator	3.1	1.7		3.5	3.5		2.9	1.5		2.7	1.0		4.0	1.5		4.0	1.0
Adminstrator	1.8			1.0			2.0			1.7			1.0			4.0	
Supervisor	2.8	2.7		2.5	3.0		2.8	2.0		2.5	1.5		4.0	4.0		3.5	3.0
Supervisor	2.9	1.4		2.0	1.5		3.0	1.0		2.5	1.5		4.0	1.0		4.0	2.0
Supervisor	3.0	1.4		2.8	2.5		3.0	1.0		2.5	1.0		4.0	1.0		4.0	1.5
Analyst	3.0	2.0		3.0	2.5		2.9	1.5		2.3	1.5		4.0	1.5		4.0	3.0
Analyst	2.9	2.9		2.0	2.5		2.9	3.0		3.3	3.0		2.5	4.0		4.0	2.0
Analyst	3.0	1.8		3.5	3.0		3.0	2.0		2.3	1.5		4.0	1.0		3.0	1.5
Analyst	3.0	1.6		3.0	1.5		3.0	1.5		3.2	1.0		4.0	2.5		1.5	1.5
Average	2.8	1.7		2.7	2.2		2.8	1.5		2.5	1.5		3.5	1.7		3.4	1.8
n	14.0	13.0		14.0	13.0		14.0	13.0		14.0	13.0		14.0	13.0		14.0	13.0
s^2	0.1	0.3		0.8	0.7		0.1	0.3		0.2	0.3		1.2	1.2		1.0	0.6
F		0.4			1.2			0.4			0.6			1.0			1.9
Ftest		6%			62%			4%			15%			53%			85%
Ttest		100%			84%			100%			100%			100%			100%
Significance of T		Yes			No			Yes			Yes			Yes			Yes

9.6 Observations

Table 9.2: Raw data from observations at Learning Factory

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
Ability to relate Business Improvement to their environment	Struggled to understand customer in the context of operation	High awareness of their customers and related to their context and customers often Types of thinking required in BI not understood Experiential learning activity to illustrate the difference between special cause and common cause was well received and understood
Ability to identify and differentiate between the types of waste	Waste vs Value, the conversation around value in relation to customer was difficult without initial understanding on customer. Debriefed and differentiated between the different types of waste. Delegates could relate this to their work places quite easily as well.	Waste vs Value - work sampling activity data helped them make the connection as they could see the small percentage of Value Adding work in relation to Non-Value Adding work. When it came to the eight types of waste, these were understood both theoretically and practically as participants were able to spot them during the waste walk in the Learning Factory employees. The delegates got to appreciate that the three principles of sustainable BI are interlinked as they were busy with a technical activity but had not considered the aspect of mindsets and capabilities and impact it has on technical success.

Observation criteria	Group 1 – Mineral processing operation	Group 2 – Operations support services
		On the technical side, the identification of the wastes during the activity was well executed and the learning during the activity was apparent.
Are participants able to follow a structured problem solving methodology	Were able to extend this concept process mapping to their operational problem easily. When the teams were exposed to Problem Solving the initial inclination was to jump to solutions before defining the problem statement and the problem scope. Using the Kipling method (5W1H- WWWWWH) to define a problem statement seemed easy at first glance but the participants realised that this was challenging as they attempted to do it. They applied the tool to an everyday example and found they needed clarity in interpreting their answers. The importance of a well-defined problem statement became clear as they exercised and practised coming up with statements and this helped in defining clear problem scopes for the Learning Factory.	Process mapping was completed practically by observing the activities in the Learning Factory and this was well understood When the participants responded to the wastes observed in the Learning Factory they easily gave solutions to the perceived problem as typically expected if you do not intentionally do an issue investigation. They were familiar with Kaizen as a problem solving methodology.
Do participants know how to use RCA tools	Participants could articulate how doing a proper fishbone to identify the root cause of a problem could lead to quicker resolution of breakdowns at their operation.	Only four participants had used RCA tools prior to the training. During the training, they applied the tools on a day-to-day example and to the Learning Factory scenario to identify root causes. Key takeaway was that the process boundaries need to

Observation criteria	**Group 1 – Mineral processing operation**	**Group 2 – Operations support services**
	The Five Why tool was known by all but has not always been used appropriately and has been ineffective when used at their operation.	be well defined first and the importance of a process map was highlighted. With Five Why, the key learning was the importance of asking the right question to get to the root cause and without focus it is easy to digress.
Ability to manage bias in brainstorming	Participants realised through the examples they did that they needed to have a clearly defined statement as an ambiguous statement could be interpreted differently.	Key learning was that they needed to manage bias caused by rank and other classes especially when it came to voting.

Table 9.3: Group 2 observations raw data

Content	Observations during training	Observations in application in project kickoff
BI - context within the organisation Overview of the Operating Model	Participants seemed far from content when session kicked off with wide randing answers during the theoretical session. Interesting to note is that this group had a high awareness of their customers and related to their context and customers often. Experiential learning activity to illustrate the difference between special cause and common cause was well received and well understood. it also helped participants understand Statistical Process Control tools like control charts and capability histograms as they designed their own. There was marked engagement and seeking of clarity on issue of stabilty first before capability which seemed better understood through the activity	Application of this concepts is hard to measure as it is part of the overall context and is observed in each of the topics that were taught
Focus on the Feedback Process		
· Measures process		
· Analyse and Improve process		
· Overview of Decision making tools used in Process Performance Review		
Business Improvement What is Business Improvement?	Defintion of Business Improvement and elements of Sustainable BI where well understood when they were taught theoretically and participants grappled with the content through asking questions. It appeared as if it was more head knowledge at this stage. through activities like Waste walk, these concepts started to resurface and seemed to solidify more. Types of thinking required in BI did not seem to be well understood upon being taught - audience did not engage with this concept.	Application of this concepts is hard to measure as it is part of the overall context and is observed in each of the topics that were taught
Origins of BI methods (Lean, Six Sigma, TOC)		
Elements of Sustainable BI		
· Management Infrastructure: Operating Model and the A&I process		
· Mindsets and capabilities: People in the process		

Content	Observations during training	Observations in application in project kickoff
· Technical system: Object process and macro mapping		
Types of thinking required in BI		
Issue Investigation - Problem Solving Generic process of problem solving and how it links to A&I	When the participants responded to the wastes observed in the Learning Factory they easily gave solutions to the perceived problem as typically expected if you do not intentionally do an issue investigation. They were familiar with Kaizen as a problem solving methodology. Related the problem solving methodology to the types of thinking required in BI.	The use of A&I as a problem solving methodology did not come naturally to the teams and they had to be continually directed back to the overall process. This is expected as this was the first time that they were applying it. Long term, the teams will need to continue practising this methodology on future problems to ensure that a consistent tool is used.
A3 concept as a management and communication tool		
Importance of metric tracking		
Value vs Waste Understanding different types of work	The conversation around value in relation to customer was rich and engaging theoretically. Links back to initial understanding on what is value. The same deep understanding was not demonstrated in the feedback from the the waste walk activity. The team then engaged in another work sampling activity where the data they collected helped them make the connection as they could see the small percentage of VA in relation to NVA work	Concepts of Value vs Waste came out during the Root Cause Analysis as they had another lens that they could use to view the current challenges. The answers that came out sought to identify were waste was in the process and how the waste was contributing to their problem

Content	Observations during training	Observations in application in project kickoff
Defining the 8 Wastes	Understood both theoretically and participants were able to spot them during the waste walk in the interaction with Learning Factory employees. They also debriefed and differentiated between the different types of waste. Delegates could relate this to their work places quite easily as well	
Preparing for a waste walk	Preparation was poor - and this was clear in the execution of the activity. Questions were not well prepared, strategy to approach employees was not clearly defined. The delegates got to appreciate that the three principles of sustainable BI are interlinked as they were busy with a technical activity but had not considered the aspect of mindsets and capabilities and impact it has on technical success.	
Identifying the 8 wastes in a process (execute waste walk)	The identification of the wastes during the activity was well executed and the learning during the activity was apparent.	
Gathering data for value adding vs non-value adding work	Not well done - links back to understanding different types of work	
Process Mapping Macro Map and Value Flow Map	This activity was completed practically by observing the activities in the Learning Factory and this was well understood	The initial finding that this activity was well understood was confirmed in the project planning sessions as all groups had well-defined macro-maps for their projects

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Problem Definition Compiling a problem statement (WWWWWH)	seemed easy at first glance but the participants realised that this was challenging as they attempted to do it. They applied the tool to an everyday example and found they needed clarity in interpreting their answers	A lot of effort went into defining the problem statement using the WWWWWH and this was well done by all but one group upfront. The group that did not use this method later struggled with explaining their scope.
Scoping the problem	they used the WWWWWH to define the problems they observed in the Learning Factory. The importance of a well defined problem statement became clear as they exercised and practised coming up with statements	The application of this tool led to robust discussions among team members and this sought to clarify the problem further and resulted in a better defined scope.
Root Cause Brain Storming Fishbone diagram	Only four participants had used RCA tools prior to the training. The applied the tools to a day-to-day example and to the learning factory to identify root causes. Key takeaway was that the process boundaries need to be well defined first and the importance of a process map was highlighted. With 5 Why, the key learning was that you need to ask the right question to get to the root cause and it is easy to digress.	At project kick-off all groups considered Root cause analysis and in particular, the fishbone diagram was used for this initial round of root cause brain storming. The application of this tool was done correctly by most groups while one group opted to discuss how it will be used in subsequent investigations.
5 Why's		

Content	Observations during training	Observations in application in project kickoff
Brainstorming potential control action ideas Concept of brain storming (Do's and Don'ts)	Divergent thinking to generate ideas and convergent thinking to voting on the top issues. They realised through the examples they did that they needed to be same statement could be interpreted differently. Another key learning was that they needed to manage bias caused by rank and other classes especially when it came to voting.	This was not observed in the preliminary kick-off of projects as the groups had not advanced to this stage
· Affinity diagrams		
· Grouping		
Error Proofing		
Improvement selection		
· Ranking and selection tools		