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Improving Productivity of Work Integrated Learning by the Application of Lean Principles

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Abstract

The use of Kaizen tools in Work integrated learning (WIL) has a positive impact to productivity and employability of Mechanical Engineering when they demonstrate the ability to curb the eight wastes in manufacturing. Lean manufacturing is in high demand globally and incorporating it to WIL help eliminate the 8 wastes in Lean manufacturing and service industries. The paper explores the significance of Lean Manufacturing (LM) to Work integrated Learning (WIL) specifically Mechanical Engineering value addition is critical to meet customer needs at minimum costs. The set productivity targets are attained through continuous improvement (CI) and Standard Operating procedure. WIL students are involved in CI at their workstations where they do a self-evaluation and reflection exercise upon completing the task to quantify improvements.

Keywords
Collaboration, productivity, employability, waste, self-evaluation.

1. Introduction
The study seeks to establish whether the industrial training of mechanical engineering students from universities of technology in South Africa in their last semesters make them gain practical and professional skills that secures them employment. The traditional University education rarely provide graduates with employability skills required by the industry. The gap between the university education and industrial is bridged Work Integrated Learning (WIL) whose effectiveness is demonstrated in this study. The Paper provide empirical evidence on the benefits and barriers of WIL from students and coordinators perspective.

The goal of lean manufacturing is to be able to deliver the exact product in the exact quantity with the exact quality that the customer needs in time. It introduces the uses of the theory of constraints method to identify the bottlenecks and systematically eliminate the constraint. This can be done in Mechanical Engineering (ME) subjects during laboratory work.

The study considers the Lean philosophy and its application to industry, by WIL students in three modules. The first module is Work Readiness which is covered in a semester and is a prerequisite industry for WIL placement where the WIL students learn the Lean manufacturing principles.

The second module is Mechanical Engineering Practice I which develops hand skills for the students during the first six months of industrial placement and is done at the Training Centres. The training centres provide general and specialised training as per individual industry requirements. Big companies have their own Training centres. The third is the six-month Mechanical Engineering practice II which is done at the workplace (industry) where the students' initiate projects for problem-solving using the continuous improvement principle. The literature will consider the importance of collaboration, contracts with industries, feedback from industries and Universities, and the role of WIL in employability improvements.

1.1 Background

The productivity of an industry is about improving outputs whilst inputs decrease. Manufacturing industries need to produce products that meet the customer value needs. In the manufacturing not all products are perfect, but some are defective and considered as rejects. In the service industry, the service provided must satisfy the community or customer. It the outputs are less in value than the inputs the business becomes less profitable, and its growth will be limited to external funding instead of self-funding.

The Work Integrated Learning program (WIL) for student in Mechanical Engineering (ME) aims to improve productivity at work for the host company to benefit. It is paramount therefore for all WIL students in ME to undergo a work readiness program to learn and apply the basics of Lean Manufacturing (LM). This digital knowledge and skill will improve productivity during WIL (Jewpanya et al., 2023).

1.2 Research questions

RQ1 What principles are used to optimise employability of the ME student?
RQ2 Are collaborations between Universities and industry effective for WIL placement ?
RQ3 Is the training with collaborators meeting the industry skills requirements?

1.3 Research Objectives

RO1 Identify the Lean techniques for Kaizen improvements
RO2 Identify the companies that Collaborate with learning institutions in WIL
RO3 Obtain the effect of WIL to the employability of graduates

1.4 Scope

The paper covers the three WIL modules work readiness Mechanical Engineering Practice I and II used to introduce and enhance Lean manufacturing principles to Mechanical Engineering.

1.5 Significance

The study highlighted the importance of WIL and the benefits of WIL practice to industry. These benefits increase the employability and employment opportunities for Mechanical Engineering students.

2. Literature Review

The section will consider the three levels of WIL, the basic lean principles and their application, and the benefits of WIL to the student and industry. The University provide the content and theoretical knowledge problem solving techniques whilst the industry that provides WIL applies this knowledge to add value in the manufacturing and service industry. The academics (Taylor & Calitz, 2020) hinted about the use of advisory boards to improve and maintain the quality of the learning program. In ME, the University, industry, the Engineering professional, and the Voluntary constitute the advisory board that develops and continuously improves the WIL program. New technologies are shared developed and incorporated to the learning curriculum when recommended by the advisory board.

The study by (Nuangpirom et al., 2023) recommended that institutions work in partnership with workplaces that contribute significantly to WIL experiences. The industrial partners help to develop the suitable curriculum for the Mechanical Engineering through their inputs in the surveys and Advisory boards. The standard policy by the industry to protect equipment from damage is to attach the trainee to a suitable training Centre for four to six months to obtain the skills before he uses the company equipment. The University also established MOUs with training centres such as the Gijima Training Centre for power stations, and the Coal Training Centre (CTC) for coal mines before they work in the factory.

(Dean, 2024); (Langton, Maotoawe, & Mafini, 2023) and (Allu, 2019) strongly recommended the importance of collaborations with industry and Training Centres to improve Engineering Learning. The roles of each partner are clearly defined to train assess and evaluate WIL students and create experiential training opportunities after graduation.

The study by (Teeling, Dewing, & Baldie, 2020) on the divergence theory, illustrated the art of learning by discovery which the Training Centres use apply to develop hands-on skills from the classic laws of motion in mechanical engineering practice. Reflections are done at the end of each shift to evaluate the training and identify improvements that are needed.

(Bilgin, Rowe, & Clark, 2024) considered (WIL) to be a valuable pedagogical strategy for learning and developing work skills experience. The second phase of WILis done in industry where students initiate and conduct a project that benefits the company during plant operations. Management and WIL students reflect on the project stage by stage to assess and evaluate progress.

(O'Neill, 2024) discussed the authenticity and consistence of the student-mentor and their relationship, such as approachable, accessible, knowledgeable about topic, effective communicator, encourages/cares for students, good listener and confidence. This prepares the workplace for experiential learning programme. Relationship building for mentors to facilitate learning by being patient, approachable and understanding, and satisfying the student's need to feel valued and safe is critical (Bilgin, Rowe, & Clark, 2024).

(O'Sullivan, 2024) recommended that Coordinators and mentors should portray excellent values and behaviours in the workplace so that students see them as role models. WIL coordinators help the student plan learning activities, how to probe questions for the 5Ws, understand the student's level of learning and how to deliver constructive feedback. This builds good relations that invest time in the placement, developing and building competence in students.

(Effendi, Widjanarko, & Sugandini, 2021) and (Lodgaard et al., 2016) singled out technology as critical in CI. The application of green technologies reduces costs, create employment, (Allu, 2019)and sustain the environments. Continuous Improvement (CI) can be small incremental changes in products and processes for enhanced business performance or company-wide process of focused and continuous incremental innovation. Radical improvements are attained through an capital investment technology mainly from manual and semi-automatic machines to full automatic computerised numerical control (CNC) and robotic.

The gap to be filled by the Work readiness module is to expose students to the Kaizens such as PDCA,7S, Poka Yoka, Single Minute exchange of Dies(SMED), Root Cause Analysis (RCA) and the 5WHY analysis which are used frequently in problem diagnosis in Manufacturing plant and laboratories equipment (pumps, boilers, and other equipment). This complies with the academic work by (Becerra-Flores, Salas-Sotelo, & Corzo-Chavez, 2024) that identified and recommended similar lean techniques for CI.

(Jessani, Kumar, & Gul, 2024) demonstrated that productivity in service and manufacturing industries is improved by reducing the 8 wastes. These wastes are defined by the acronym DOWNTIME where: D- production of parts with defects, O- overproduction , W -is waiting without adding value, N- non utilisation of staff talents, T – transport (taking longer routes), I – creating too much inventory, M- motions that add no value and E -extra processing (value which the customer).

(Duran & Mertol, 2020)'s recommended the alignment of the curriculum to techniques that improves productivity and employability of University Graduates. The incumbents must add value to their work by reducing wastes and improving quality. To achieve CI at Universities the curriculum must be developed to prepare the students for the workplace whilst practising continuous improvement using the Kaizen principle.

(Taufik, 2020) hinted that the PDCA is important in project management during WIL. It guides the student what to do first and what's next. The planning is done before doing the task to ensure that the task is achievable. When the task is done reflect and check the best practice used and take action to correct any anomalies before setting the SoPs. (Singh & Gandhi, 2024) highlighted that the benefits of the PDCA technique is the reduction of the eight wastes in the internal logistics, find the root cause, improve performance by continuous improvement and satisfy the workers and customers.

(Anpo et al., 2021) and (Holifahtus Sakdiyah, Eltivia, & Afandi, 2022) recommend the use of the 5Ws framework of the RCA principle to determine the root cause of the problem in the 4Ms domain in engineering. The 5WHY interrogation gets to the root cause of any problem in manufacturing and service industry. In the study the WIL student will apply the concept in breakdown fault finding, product design when failure or inefficiency problem is identified. (Ahmedani, 2020) and (Widayanti et al., 2020) supports the use of the 5WHY interrogation in problem solving on the daily manufacturing process. It involves human interactions in CI in the manufacturing projects. During WIL the 5WHY analysis will interrogate the cause of a defect or machine failure until they get to the root cause of a problem. (Becerra-Flores, Salas-Sotelo, & Corzo-Chavez, 2024) and (Uhanovita A.C, K.A.T.O, & Parameswaran, 2023) recommends the use of the Poka yoke principle to reduce variation by redesign of components to ease the manufacturing process and improve efficiency. The principle has three types of Poka Yoke namely shutdown, control, and warning that can be installed on each machine or die. They are activated by contact, motion, and fixed value. (Vieira., 2021) and (Santos et al., 2022) recommended the use of the single-minute exchange of dies (SMED) principle to be developed and applied in the manufacturing industry. The principle reduces equipment preparation, setting, and replacement time when changing the manufacturing tools and dies. The focus of the SMED is to minimize the setting up time and increase efficiency.

(Sukdeo, Ramdass, & Petja, 2020) and (Añazco-Alavedra & Quiroz-Flores, 2024) demonstrated how the 7S housekeeping Kaizen is used to reduce the DOWNTIME. It is in the Work Readiness module to help WIL students sustain a standard of work and ethics commensurate with the organization and Engineering Councils.

(Sukdeo, Ramdass, & Petja, 2020) and (Fernández Carrera et al., 2021) identified and illustrated the 7S are used at the workplace. The 1st S is Sort that removes all unwanted items from the workbench to the red tag area. The 2nd is Set in order used to arrange items in the sequence in which they will be used whilst the 3rd is "Smart" used to ensure a clean workbench to increase visibility. The Smart S involves hazardous liquids spillage solid particles, and any form of dirt that reduces productivity. The 4th is Standardize used to set the Standard operating procedures (SOPs) which must be sustained by the 5t S which Sustenance. The 6th S is Safety which is covered in Occupational Health and Safety Act. The 7th S is the spirit and security of workers that enhances job satisfaction through fringe benefits such as insurances and other subsidies.

3. Methodology

The field and literature survey, work-study and interviews with mentors, students' oral presentations and reports methods would be used to obtain both quantitative and qualitative data for analysis to determine the impact of incorporating the Kaizens in the WIL modules. The performance improvement by each Kaizen helps to identify their significance to WIL.

4. Data Collection

The data collection and compilation of performance graphs is important in performance monitoring, identifying in efficiencies, making data driven decisions and effective communication. The WIL student were participant observers in the Gemba walk where they identified improvements required on each machine. The operator records the machine behaviour periodically and when there is an anomaly. The number of stoppages and adjustment done on the machine are recorded in the data sheet. This will be presented to the line manager and improvements are done respectively. By studying the production statistics and trends in the plant the study would areas that require improvement. A question for operators to respond is used to get their opinions and requirements.

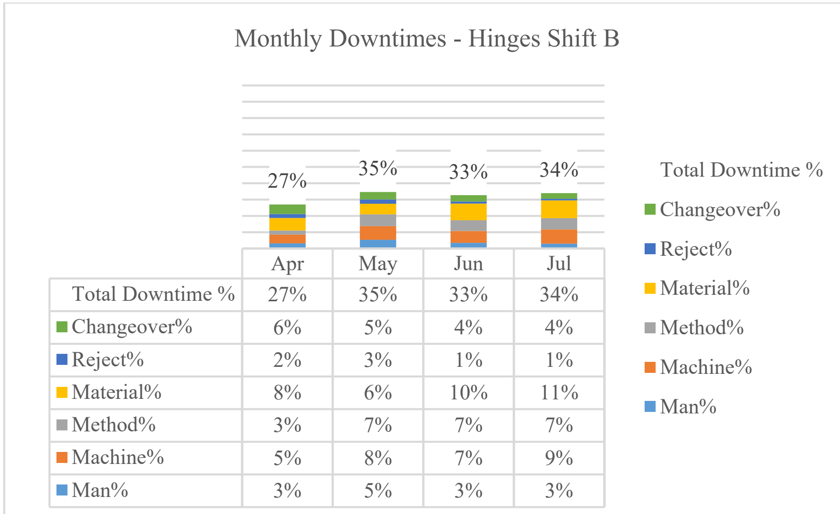
5. Results and Discussions

The results obtained were presented in this section in numerical and graphical form. The statistics were obtained from the work study during the Gemba walk.

5.1 Numerical analysis of results

Using the time study approach and a stopwatch, the WIL students compiled results shown in the Figure 1. The materials were 8% at the start, went down to 6% then rose to 11% in July. To resolve the problem collaboration with the suppliers was necessary to supply the materials that have been annealed and stress relieved to prevent cracking during bending.

The Change over times contributed 6% of downtimes and the problem was resolved by using clamps instead of threaded fasteners to reduce it to 4%. The machine downtimes were 5% and increases to 9% in July 2021. Training and developing SOPs was used to resolve the problem. After training the operators were allowed to stop and adjust the machines at the onset of the defect following the standards set. WIL students go on Gemba walk and report back in the daily tea talk meetings where the team brainstorms and develops solution



	Apr	May	Jun	Jul
Total Downtime %	27%	35%	33%	34%
Changeover%	6%	5%	4%	4%
Reject%	2%	3%	1%	1%
Material%	8%	6%	10%	11%
Method%	3%	7%	7%	7%
Machine%	5%	8%	7%	9%
Man%	3%	5%	3%	3%

Figure 1. Downtimes determined by work study method by WIL students (company)

The WIL students calculated and plotted performance graphs that are analysed and evaluated by the RCA model to determine the causes of breakdowns and defects. Design out Maintenance strategies are used to make plant maintenance decisions such as service, replace, overhaul, or shut down the plant.

Figure 2 shows the effectiveness graph at the door hinge section for the A shift from the month of May to 2022 to February 2023. The effectiveness of the production ranged from 54% to 68% compared the 80% target. This will require continuous improvement initiatives at all levels to improve the productivity. The eight wastes have to be reduced on all the 4Ms and consider investing in error proof machines.

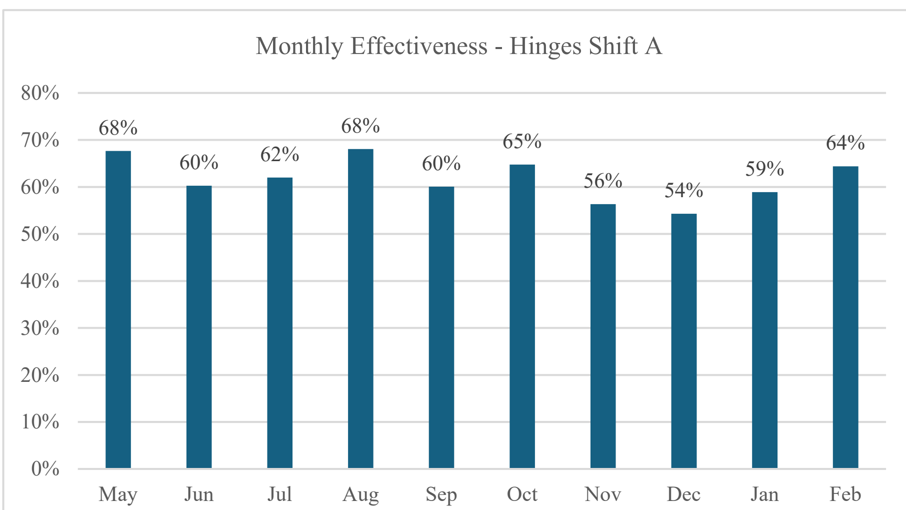


Figure 2. Effectiveness of hinge production in shift A (Company)

5.2 Graphical Analysis

The equipment Mean Time between Failure (MTBF) $MTBF = \frac{\text{sum of the operational periods}}{\text{number of observed failures}}$

Marked improvements in the reduction of equipment breakdown and the Mean Time to Repair (MTTR) was reduced when the Total Productive Maintenance (TPM) lean strategy was applied.

$$MTTR = \frac{Total\ corrective\ maintanance\ time\ month}{Number\ of\ corrective\ maintanance\ actions\ per\ month}$$

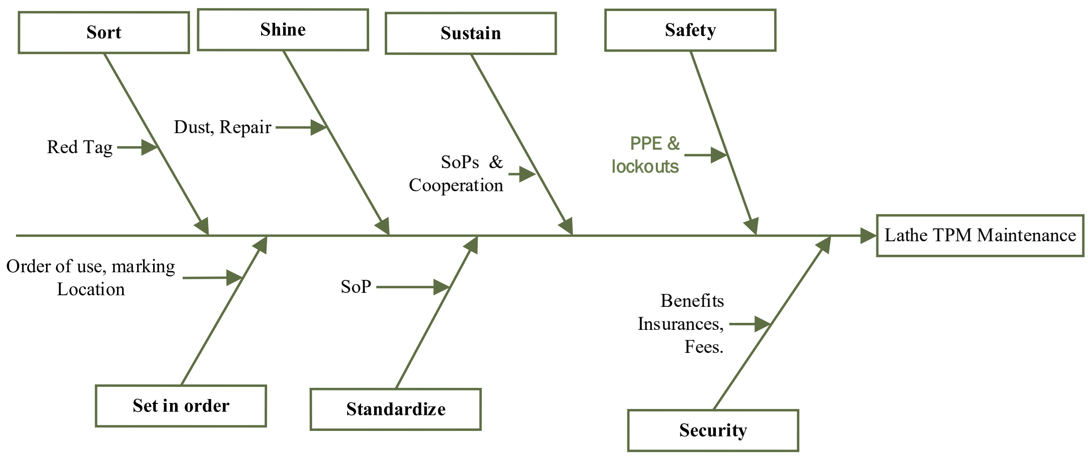


Figure 3. The 7S for Lathe Machine Maintenance Framework (Author)

The 7S principle is applied for housekeeping in any workplace. Figure 3 shows how the 7S has been applied in the maintenance of a lathe machine. For any task that needs to be done Sort and remove all unwanted materials and place them at the Red tag area to prevent time wastage due to mixed tools and consumables. Setting in order allows the equipment to be arranged in the order in which they are used, and Shine is cleaning the workbench and tools to increase visibility. Standardise is the setting of Standard operating procedures that must be sustained. Personal protective equipment and lockout for the operator and machine respectively is critical for the safety of the operator and machine.

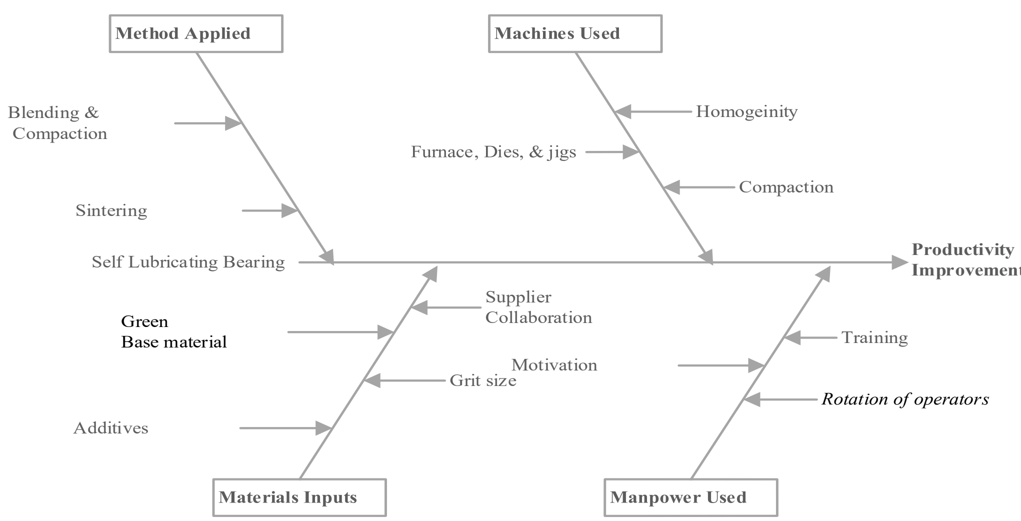


Figure 4. Application of the RCA in Manufacturing Framework

Figure 4 shows the impact of 4Ms in manufacturing. The decrease in reject ratio, rate of production, takt time, and downtime increased the Overall equipment effectiveness (OEE) in a production plant. When the WIL student applied the cause-and-effect analysis that was presented for brainstorming, the (OEE) improved by 3.2%. The disparity was caused by a lack of rotation.

The 8-waste walk applied to manufacturing and service industries revealed large losses in municipalities, government, and non- profit-making organizations. The Municipal industries selected waste an average of 615 min (10.25hrs) per week whilst non-lean private manufacturing industries waste about 142 min (2.36hrs). The lean manufacturing industries on average waste less than 50 minutes per 9-hour shift.

5.3 Proposed improvements

During ME Practice I, a cohesive blended learning approach that involves laboratory work, report writing, oral presentation skills, and brainstorming during tea talk meetings to address and solve the technical needs of the work tasks under the supervision of a Professional Engineer. The engineering ethics and values are assessed by the Professional Engineer who is guided by the Engineering Council code of conduct.

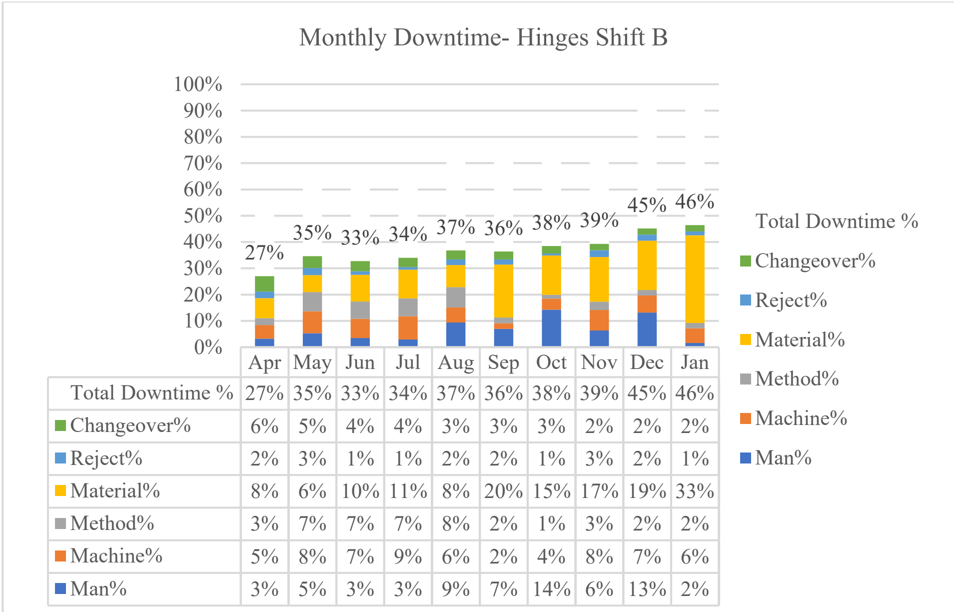
As the WIL students progress to ME Practice II, the scaffolding approach is applied during plant operations where the problem is diverse and increasingly challenging. To solve mini projects, one must integrate more subjects, teamwork, and interdisciplinary learning where safety, costing, and environmental skills are required. Effective technical writing skills are necessary at this level because of the cross-disciplinary approach to product design and manufacture.
The targeted approach tied to the learning outcomes of a specific course such as Steam plant and maintenance in Thermal power stations is also involved in practice II. Many industrial partners have acquired new software to solve different Engineering problems as targeted by the projects. Knowledge, understanding, and use of Drawing & Design software have opened gates for ME students to get WIL in Consulting Engineering companies where design software is used.

Finally, is the is the diverse approach that is applied in big projects such as Ship Building by SANDOCK, Murray and Roberts in Bridge, and Skyscraper Construction. The big projects apply learning outcomes that demonstrate critical analytical thinking in solving macro problems in projects.

5.4 Validation

At tea talk meeting is held to discuss the challenges encountered and how they were resolved. This reflection is used for continuous improvement of each section in the production unit. Brainstorming is used to resolve the issues before starting. Figure 5 shows how the materials affected the downtimes in the door hinge production section. Although the material was 100% correct the hinge blanks were cut in the wrong direction that caused the blanks to crack during bending. The sheet bending is done across grain to prevent cracking.

The success of WIL was also attributed to peer mentoring groups set up by the department to offer flexibility, inclusiveness, and knowledge sharing among the senior and junior students. Peer mentoring facilitates interdependence and networking among the students. The networking has successfully made the students to progress and do the advanced diploma through distance education as part of personal growth. The attendance of workshops and seminars offered by engineering councils and mechanical engineering institutions also enhanced personal growth, friendships, and establish a safe environment and skills development.



	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Total Downtime %	27%	35%	33%	34%	37%	36%	38%	39%	45%	46%
Changeover%	6%	5%	4%	4%	3%	3%	3%	2%	2%	2%
Reject%	2%	3%	1%	1%	2%	2%	1%	3%	2%	1%
Material%	8%	6%	10%	11%	8%	20%	15%	17%	19%	33%
Method%	3%	7%	7%	7%	8%	2%	1%	3%	2%	2%
Machine%	5%	8%	7%	9%	6%	2%	4%	8%	7%	6%
Man%	3%	5%	3%	3%	9%	7%	14%	6%	13%	2%

Figure 5. Downtime statistics

Teaching the Kaizen principles to WIL students during work readiness optimise their employability because of the improvements they do during WIL. The collaborations between universities and industry is effective for WIL placement and employability because the training curriculum is tailor made to meet requirements by industry. The training done at the training centres is tailor made the specific industries. Power stations, coal. platinum and gold mines have specific training centres which meet their requirements. Iron and steel production companies have well established inhouse training centres for both WIL and candidate engineers.

6. Conclusion

When introducing a new manufacturing philosophy resistance is inevitable. It is critical for one to first fit in the existing company culture. Use of the local language is rampant among the workforce who appreciate the diversity and respect for people. In South Africa where there is high diversity, companies developed a communication language to cater for more than 11 South African indigenous languages. New employees go through an induction, Safety and Orientation training program to remove the inevitable emotional and stressful culture clashes brewed when staff interact with unfamiliar people in unfamiliar circumstances. The Kaizen 4Ps principle is key to productivity improvement because of its holistic approach to a workplace. It involves the people, the physical workplace, the processes, and their performances.

Mass and batch production produces excess, defective and rework products that generate large inventory that consume space and disturb motion. Lean manufacturing thrives to increase the output at reduced input by eliminating the 8 wastes. Lean philosophy is mistaking proof whilst Mass and batch production is fool proof. Mistake proof implies 100% quality checking at all the manufacturing stations and does not allow defect to be passed to the next process. Lean manufacturing expels wrong attitudes from workers, and they migrate from blaming or giving excuses to stop and ask if in doubt.

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