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Implementing Digitalised Lean Manufacturing Training in a UK Engine Manufacturing Centre During the SARS-CoV2 Pandemic of 2020

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Abstract

This paper examines a novel way of training Lean Manufacturing Systems and Tools utilising an Industry 4.0 methodology during the SARS-COVID2 Pandemic of 2020. Currently, it is challenging for the Integrated Production Systems Team, responsible for carrying out training on the Lean principles, to undertake the training safely and without the risk of possible disease transmission. This is due to the usual close quarters training carried out in the Engine Manufacturing Centre. Schools, Colleges and Universities have adapted and utilised technology and moved to an Industry 4.0 digitalised approach to learning and development. This is therefore an opportunity for manufacturing to follow suit and create digitised solutions to training and development opportunities, to ensure that the employees within the manufacturing facility have adequate knowledge on the Lean principles.

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1. Introduction to Research

This paper forms part of ongoing research into implementing Lean Systems and Tools, also known as Lean principles in an Engine Manufacturing Centre (EMC) in the United Kingdom.

1.1. Introduction to Paper

This paper investigates a method of implementing Lean principles training in the EMC during the SARS-CoV2 pandemic of 2020. Prior to this, training on Lean principles at the EMC was predominately classroom based. However, due to the pandemic there were two issues with continuing to do classroom training:

The first issue was that, during the first UK National Lockdown which began on the 23rd of March 2020, there were

around 200 employees working from home. The second issue, when employees began to return from furlough, week commencing 18th of May, social distancing measures meant that classroom training again was inhibited due to the risks associated with close quarter working and disease transmission. It was therefore important to examine new innovative ways of training employees in Lean principles. The researchers investigated Industry 4.0 theory to integrate computer systems and implement online digitalised training that would be made available to a wider scope of employees. Research in other manufacturing organisations has previously proven that there are advantages to cross utilising technologies and manufacturing methodologies [1-3].

Within this study, Section 1 will investigate the COVID-19 Pandemic, Social Distancing, Industry 4.0, Education 4.0 and Lean Manufacturing. Section 2: Methodology defines the way technology has been utilised to deliver training to employees at home during the UK National Lockdown and how the digital training has been used as employees return to the EMC. Section 3: Results will examine how many employees have attempted and successfully passed the training in two different stages of the UK National Lockdown, Stage 1: working from home and Stage 2: gradually returning to the workplace from home working. The results also detail pre-pandemic classroom-based training compared to the digital training. Section 4: Discussion will deliberate the results and the study. Finally, Section 5 will conclude the findings of this study.

1.2. Covid-19 Pandemic

Coronavirus Disease 2019 (COVID-19) is a pandemic that was first reported on December 31, 2019 in Wuhan, China [4]. The disease is caused by the virus SARS-CoV2. SARS-CoV2 emerged as a highly pathogenic coronavirus in humans, after Middle East Respiratory Syndrome coronavirus (MERS-CoV) and Severe Acute Respiratory Syndrome coronavirus (SARS-CoV) in the twenty-first century [5]. On the 11th of March 2020, the World Health Organisation (WHO) declared the coronavirus disease 2019 (COVID-19) a pandemic [6]. By the 23rd of March the Prime Minister for the UK, Boris Johnson, announced the UK lockdown and by the 26th of March, the Health Protection Coronavirus Restrictions (England) Regulations 2020 were enacted [7]. On the 4th of January 2021, there had been a reported 85.6 million coronavirus cases worldwide with 1.8m deaths recorded. In the UK alone there were 2.7 million total cases with over 75,000 deaths [8].

1.3. Social Distancing

Isolating affected individuals is an effective way of controlling the spread of a disease. If the disease cannot be transferred from person to person, the disease will eventually disappear [9]. In China, the state took decisive measures to implement medical isolation for patients and close contacts, block traffic, cancel public activities, adopt face masks and encourage regular hand washing. They also implemented controls such as allowing one person from every family to go out every 2 days to purchase necessities; in public places, the distance between people in line needed to be $>2m$ [10]. Furthermore, Merirui Qian, Jianli Jiang, 2020, suggests that social distancing, involving keeping a distance of 1.5m between people, can prevent the spread of most respiratory infectious diseases. Additionally, this study mentions that social distancing is one of the most effective measures to reduce the spread of the virus. Therefore, although it is important to train people in the Lean principles within the manufacturing facility, it is important to maintain social distancing, which is difficult in the closed quarter spaces that are available. The authors chose to utilise technology to provide training and reduce social contact, maintaining social distancing.

1.4. Social Distanced Learning in Education

The Manufacturing industry isn't the only sector implementing social distancing measures and utilising technology to provide training and education. Research shows that many schools, colleges and universities around the world are dealing with similar challenges, training and educating individuals whilst maintaining social distance and minimising person to person contact and potential transmission of the disease.

Research in primary schools has shown that pupils were successful in learning to spell through the utilisation of e-learning tools such as Telegram Autobot [11]. Other studies which have been carried out have proven that the reutilisation of social networking services as e-learning platforms for early-stage learning in classrooms assisted in increasing the knowledge and motivation of pupils in English language learning [12, 13]. Therefore, it is essential that teachers have up skilled in digital transformation and technology. It is important that they have a grasp of modern technology to improve the educational approach both inside and outside of the classroom [14].

These innovative methods of online training can also be implemented in manufacturing. In all manufacturing facilities, and in particular within the EMC in question, there are an array of training and development requirements. From operational training on machines and in assembly, to more technical skills required for Engineers, Process Specialists and Managers. Therefore, the research into digitised training in schools, colleges and universities should be considered in the manufacturing environment. Especially in the current situation with the pandemic where gatherings are prohibited to prevent transmission of the disease.

1.5. Industry 4.0 and Education 4.0

The term Industry 4.0 refers to what many consider to be the 4th Industrial Revolution, which is based on the integrated use of digital technology and new levels of interconnectivity [15]. It is the newest industrial transformation and utilises robots, big data, data exchanges, cyber-physical systems, cloud technology, artificial intelligence, internet of things, and semi-autonomous industrial techniques to understand the new technologies and innovation [16]. Industry 4.0 will have a large impact on the manufacturing sector, and in particular, within the automotive industry, but it has also given new stimulus for educational transformation. As discussed in Section 1.4, there are already many examples of the utilisation of technology linked to learning in schools [11-13]. Other professionals and experts in the field of education are recognising the significant effect that technological innovation is having on the education process [16-17].

Education 4.0 is the adoption of Industry 4.0 theory in the education sector and affects all domains (cognitive affective and psychomotor) [15]. Not only is Education 4.0 important as a new digitised method of training and educating individuals, it is also important as the 4th Industrial Revolution will require a

workforce with adequate data and digital literacy [18]. Furthermore, education in the 4th Industrial Revolution will require the upskill of teachers in digitisation. This research examines the digitisation of training within the manufacturing environment. The IPS Team (the trainers of the Lean principles) will consider an Industry 4.0 and Education 4.0 approach, given the current requirements around social distancing in the manufacturing facility, to ensure that adequate training and development on Lean Manufacturing continues, regardless of the current pandemic.

1.6. Lean Manufacturing

Lean Manufacturing, or ‘Lean’ as it is often referred to, is a manufacturing practice designed to consider the costs of resources for a given objective other than the creation of value for a customer. Lean employs minimum resources for maximum output and is based on five principles: specify the value by specific product; identify the value stream for each product; make the value flow without interruptions; let the customer pull value from the producer; and pursue perfection [19]. The focus of Lean is around the elimination of waste [20, 21]. However, Lean is becoming more than just a production tool, but an all-encompassing business ideology which incorporates all aspects of value streams as opposed to individual production processes [22].

The following Lean principles are utilised at the EMC and therefore require a digitised training option due to the social distancing requirements [23].

- **Problem Solving** – Concern and Corrective Action Reporting (CCAR) / Level Zero / Practical Problem Solving (PPS). CCAR, Level Zero and PPS are a three staged approach to standardised problem solving within the EMC. The standardised approach includes escalation routes.

- **5S** – Supporting Standardised working a method of Sorting, Setting, Shining, Standardising and Sustaining the working environment.
- **Standardised Work** and Standard Work Confirmation (SWC) – A standardised working approach to the manufacture of engines within the EMC. SWC is a method of auditing the standard work to identify problems with standardised working and opportunities for improvement.
- **Versatility Matrix** – A visual management tool that provides a structured approach of monitoring and measuring skills and identifying gaps in knowledge and understanding.
- **Kaizen** – A Japanese term meaning “change for the better” describing a management philosophy based on a set of principles and values [24, 25]: top management commitment and leadership; focus on processes; Gemba (the place where things happen) improvement management; people’s participation; non-judgmental and non-blaming approach; standardisation, discipline, and constancy; experimentation and observation skills; and systemic thinking. Kaizen Continuous Improvement (CI) Methodology has been implemented and is being utilised by all employees within the EMC.
- **Process Confirmation** – A form of peer-to-peer coaching on the importance of all production systems.
- **Team Improvement Circles (TIC)** - A 10-step team-based approach to implementing an improvement.
- **Leadership Achievement Measure (LAM)** - A process of measuring the essential daily activities to be completed i.e. Work In Progress (WIP) Offline, SWC’s, Safety Walks conducted. Team Boards, Toblerones, CCARs checked, and Error Proofing completed.

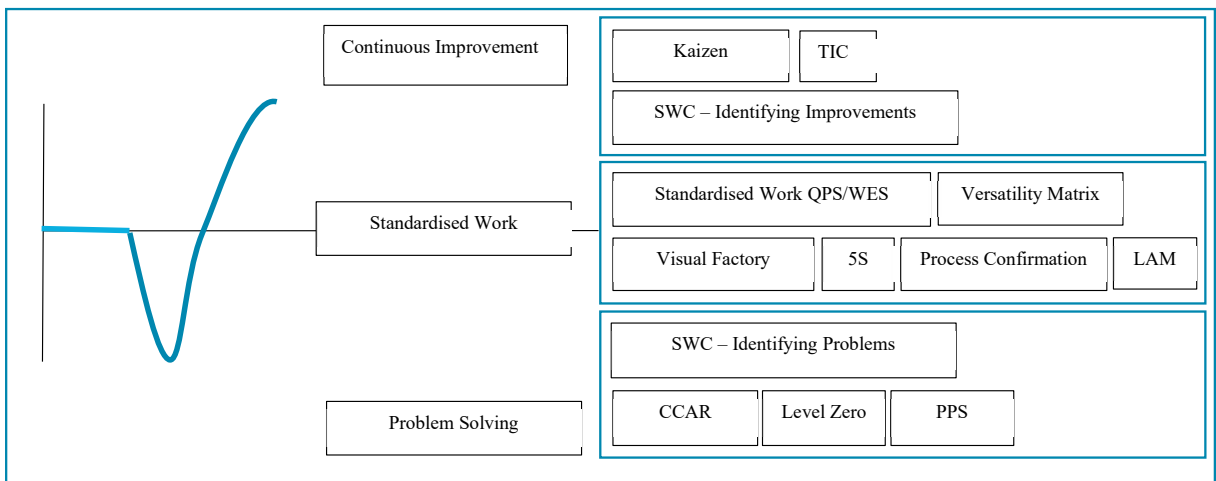


Fig .1. Integrated Production Systems / Lean Practices and how they fit.

2. Methodology

The first approach was to examine the current training material and documentation. Fig. 2 shows the current material utilised within the training and the multiple locations and systems where the training material it is stored.

The first Industry 4.0 theoretical solution was to gather the various sources of information from multiple locations and streamline them into one single source of information (Fig.2). To do this, all of the material was reviewed and the key pieces of information to be communicated in the online training were amalgamated into one “How To Guide” document (Fig. 3). This involved taking material from the training presentations, screen shots of the templates and information from the procedures and turtle diagrams. Additionally, audit findings from previous audits were also considered, for example non-conformances found from either internal or external IATF16949 audits related to Lean principles were highlighted in the How To Guide and in some instances were identified as specific questions within the 10 question assessment.

Secondly, a ten-question knowledge assessment was created on the specific Lean principle (Fig. 3) based upon the information contained within the How to Guide on a system called SuccessFactors. The question sets created were a selection of single answer, multiple choice, true or false and ordering format styled questions. In the Lean principles classroom-based training, some of the training material contained 5 multiple choice knowledge assessments that were designed to be completed at the end of the session. In the online training, this was increased to 10 questions which as described above were in multiple formats to provide additional stimulus rather than one single question type.

In the classroom-based training, the IPS Team would facilitate the training, gather the training material from the multiple locations, arrange a training room, deliver and lead the presentation and training. The key difference in online training is this facilitator role is redundant, the trainees can easily access the materials and complete the training with little to no supervision. This is where the Industry 4.0 aspect is important. As mentioned above, all of the relevant material was written into a How To Guide, which was then embedded as a link within SuccessFactors where the 10-question assessment was created. This allowed for one single location where employees could access the training material and attempt the question set, rather than having to locate all the relevant information. Thus, making the training easy to access from the company’s intranet home page. Additionally, a deep link was created from the SuccessFactors home page. This deep link could be embedded on the IPS SharePoint site as well as into emails and internal communications so that there was no need to access the intranet site and there were multiple ways of sharing the link and providing access to the online learning. Subsequently, a fully digitised training option from one single source was created to provide access to training for all employees whether working from home or working socially distanced from others within the manufacturing facility.

Fig. 3. shows the process flow for accessing the online training from the intranet site.

1. Once the intranet site was opened the initial 8 online courses could be accessed by searching the code IPS-MOS which is the acronym for Integrated Manufacturing Systems – Manufacturing Operating System. This would bring up the 8 links to the 8 online training courses, as shown in Box 1 in Fig. 3.
2. If an assessment was then selected, for instance 5S, this would then open up the IPS-MOS-101 5s Awareness course, as shown in Box 2 in Fig. 3
3. To access the How To Guide, the blue hyper link would need to be selected. This would then open up the How To Guide, as shown in Box 3 in Fig. 3
4. Finally, if “Start Course” was selected from the IPS-MOS-101 5S Awareness Course, this opened up the 10-question assessment.

The intention is for the trainee to read through the How To Guide and then answer the 10 questions identified within the assessment.

The SuccessFactors assessments have a number of rules; the questions and answers are all randomised and all 10 questions have to be answered correctly to pass the assessment. The option to check answer before moving on to the next question was added. This allowed the trainee to check if they have answered the question correctly or not before moving to the next question, but does not allow them to modify it, once the “checked” or “next” icon is selected.

SuccessFactors also allows for reports to be generated which showed who has completed the assessment with a date and time notification and how many attempts it took for the individual to pass.

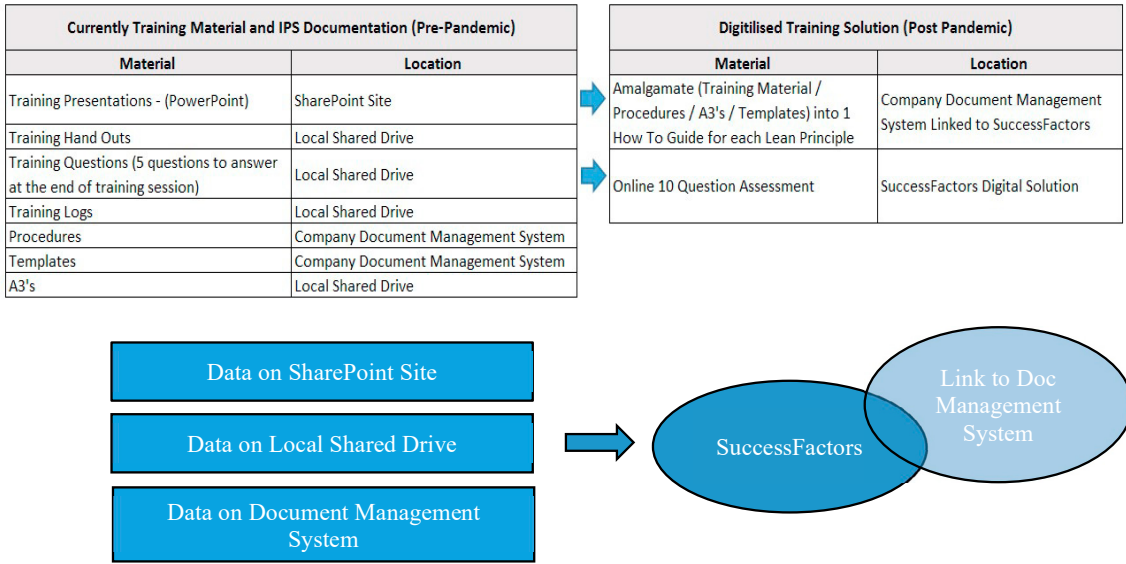


Fig .2. Current training material utilised to create digitalised training solutions.

- 1 All assessments are available on Success Factors from the Intranet
- 2 IPS-MOS-101 5S Awareness Course, accessed via link on Success Factors
- 3 5S How To Guide accessed via Hyperlink on IPS-MOS-101 5S Awareness Page
- 4 5S Success Factor Assessment Questions accessed from IPS-MOS-101 5S Awareness Page

Fig. 3. SuccessFactors with How To Guide and SuccessFactors 10 question assessment links.

3. Results

As mentioned in the introduction to the paper, there were two key drivers to implementing a digitised solution:

1. Training people working from home during the first UK National Lockdown.
2. Providing training for individuals within the EMC whilst practicing social distancing measures.

Due to these two challenges, there are two sets of results:

3.1 Results – People trained whilst working from home during the first UK National Lockdown.

Please see Table 1 for number of SuccessFactors assessments attempted and completed between the 16th of March 2020 and the 19th of May 2020. The UK went into lockdown on the 23rd of March 2020, but one week prior to the lockdown, the IPS team was developing and trialling the How To Guides and SuccessFactors 10 question assessments. The results show that there were 1,819 total attempts of the 7 SuccessFactors assessments distributed between the 16th March and 19th May by the 200 employees who were working from home during the first initial UK National Lockdown. Of those 1,819 attempts there were 608 total attempts passed, this corresponds to a 33.4% pass rate. Process Confirmation was the SuccessFactors assessment with the most total attempts passed at 144, a pass rate of 41.49%. Visual Factory was the SuccessFactors assessment with the most total attempts at 542 with 97 of those total attempted passed or a 17.89% pass rate.

3.2 Results – Training provided for individuals within the EMC whilst practicing social distancing measures.

Table 2 shows the number of IPS-MOS SuccessFactors Assessments completed in 2020 from when employees started to return from working from home on the 19th of May 2020 until 31st of December 2020. Employees started returning to the EMC from May onwards. However, in January 2021 there was still a number of roles covered by the UK furlough scheme and a number of employees working from home.

Between the 19th of May and the 31st of December 2020, the total number of IPS-MOS assessments passed was 1204 or on average 150 assessments successfully completed each month. This is more than 3 times the amount of classroom-based training on the Lean Systems and Tools undertaken, on average, each month prior to the pandemic. There were also 4318 total attempts finished on the IPS-MOS assessments. This is the equivalent of 43,180 questions on integrated productions systems attempted between May and December or 5397 attempted questions per month.

Fig. 4 shows the number of total unique users versus the total attempts. This is important as it allows the developers to examine how many unique users have attempted each assessment and how many total attempts have been undertaken by those total unique users. IPS-MOS-102 Visual Factory Awareness was attempted by 309 unique users, but had 1490 attempts, which is 4.82 attempts per user, on average, which is greater than all of the other assessments.

Fig. 5 shows the training carried out in the EMC between January 2019 and December 2020. Between 1st January 2019 and the end of February 2020 there was, on average, 50 people trained using the classroom-based training. Prior to the pandemic, the IPS Team began developing the digital based training in an attempt to provide training to a greater number of employees from across the EMC. The digital training allows flexibility for employees working shifts to undertake the training at a time that best suits them at any location within the facility, or even from home. Once the National Lockdown was implemented on the 23rd of March, the online digital training allowed the IPS team to continue to provide training to employees working from home. The graph shows that, in April, 358 employees successfully completed the training which is a 716% improvement in the number of employees successfully trained when compared to employees trained in the classroom-based training. Between the middle of May and December, the graph shows a rate of climb that corresponds with employees returning to the plant from furlough and through formally communicating the digital training across the EMC.

Table 1. IPS-MOS SuccessFactors Data from 16th March 2020 - 19th May 2020 (Working from home).

Quiz ID	Quiz Name	Total Unique Users	Total Attempts	Total Attempts Passed	Total Attempts Failed
IPS-MOS-101	5S - Awareness	44	144	39	100
IPS-MOS-102	Visual Factory - Awareness	104	542	97	438
IPS-MOS-203	Kaizen - Awareness	59	100	56	41
IPS-MOS-302	Standard Work Confirmation - Awareness	89	254	87	165
IPS-MOS-304	Process Confirmation - Awareness	122	347	144	195
IPS-MOS-701	CCAR - Awareness	106	252	99	146
IPS-MOS-702	Level Zero - Awareness	90	180	86	90
Totals		614	1819	608	1175

Table 2. IPS-MOS SuccessFactors Data from 19th May 2020 - 31st December 2020.

Quiz ID	Quiz Name	Total Unique Users	Total Attempts	Total Attempts Passed	Total Attempts Failed
IPS-MOS-101	5S - Awareness	501	1200	441	735
IPS-MOS-102	Visual Factory - Awareness	205	948	164	764
IPS-MOS-203	Kaizen - Awareness	122	295	100	187
IPS-MOS-301	QPS / WES - Awareness*	14	71	7	62
IPS-MOS-302	Standard Work Confirmation - Awareness	120	438	107	322
IPS-MOS-304	Process Confirmation - Awareness	104	266	57	199
IPS-MOS-305	Versatility Matrix – Awareness**	103	280	95	181
IPS-MOS-701	CCAR - Awareness	173	572	140	418
IPS-MOS-702	Level Zero - Awareness	111	248	93	148
Totals		1453	4318	1204	3016

Note: *Trial Assessment - Not currently in use.

Note: **Introduced September 2020

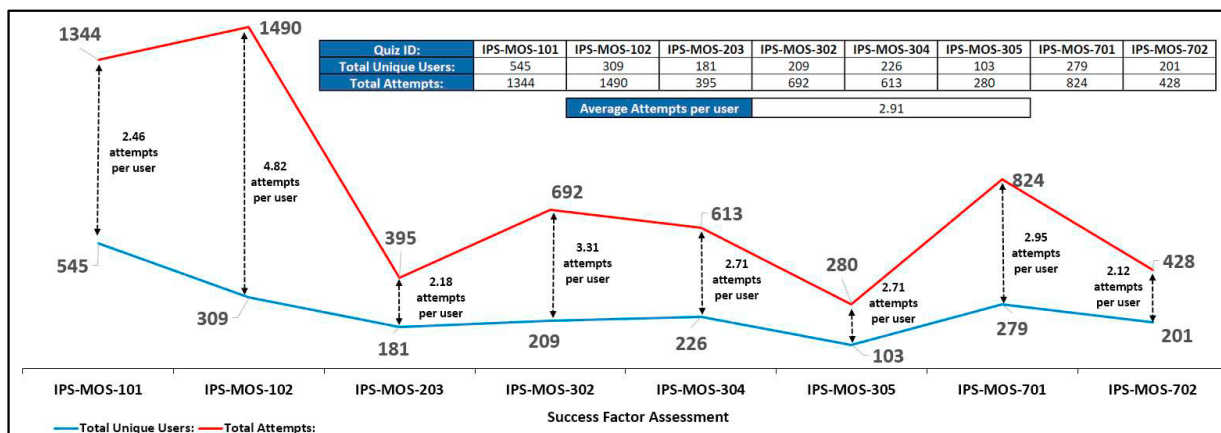


Fig 4. IPS-MOS Total unique users against the total attempts (16th March – 31st December 2020).

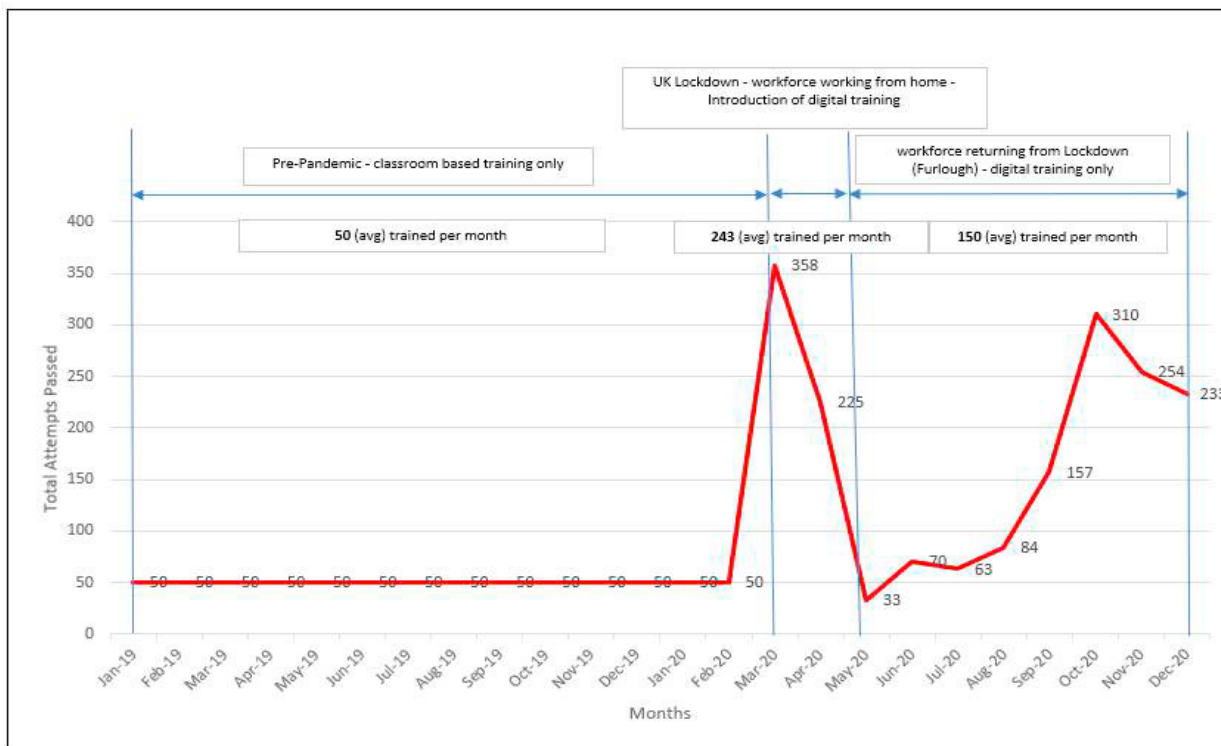


Fig 5. Graph to show training carried in EMC per month (January 2019 to December 2020).

4. Discussion

The results show that the utilisation of a digitised training solution for Lean principles has been successful within the EMC, both during the first UK National Lockdown from the 16th of March until the 19th of May 2020 and since employees returned to the EMC in subsequent months [7].

It has allowed the Integrated Production Systems Team to maintain training under socially distanced measures whilst providing a solution which is digital, Industry and Education 4.0 focused and utilises a single source solution [18].

The digital solution highlighted a number of strengths, weaknesses, opportunities and threats. In terms of strengths, it has provided easy access to training materials. The team can provide training to a greater number of employees in a variety of roles across the manufacturing facility than it could by utilising a classroom-based training approach. It has also been well received and well adopted in the manufacturing facility. The IPS team also developed a certificate in September 2020, after all the 8 assessments had been launched, which is achieved by successfully passing all 8 assessments. The certificate is signed by the EMC Director and recognised by the Institute of Engineering and Technology. This was designed to incentivise the training and recognise individuals who have completed all 8 training courses.

In terms of weaknesses, the digital training does not provide the human interaction that the classroom-based training provides. For example, if a point is not understood in the classroom it can be explained by the trainer and can be discussed by the class. Examining the results shows that IPS-MOS-102 has a high failure rate at 79%, this is in part due to not being able to discuss specific points with a trainer or the rest of the cohort in the classroom. However, this could also be viewed as an opportunity for improvement, as discussed below.

From an opportunity point of view, reviewing the results showed that the IPS systems in the plant are understood relatively well, for example IPS-MOS-203, 305, 702. However, systems such as IPS-MOS-101 and 102, which have a high failure rate, can be improved. The IPS Team can review the questionnaire data to see which questions have a high failure rate. The How To Guides can then be reviewed and more information or examples can be provided on the Systems and Tools. More work can be carried out to ensure that these System and Tools are being adhered to across the manufacturing facility, this would give some indication as to whether the training is having a positive impact. The IPS Team has also utilised the digital training to support permanent corrective actions to IATF16949 non-conformances, for example all Team Leaders and Process Leaders were asked to complete IPS-MOS-701 in response to a number of non-conformances related to the problem solving.

Threats to the process centre around potential failure of the IT systems. For example, there was an issue with the file paths of the Jaguar Land Rover (JLR) Way How To Guides which

meant that that the assessments could be accessed on SuccessFactors but the JLR Way How To Guides were unavailable. Fortunately, on the IPS-MOS SuccessFactors homepage, contact details were added which meant that the trainees were able to contact the IPS Team and inform them of the issue.

Looking to the future, the IPS Team are going to add further IPS-MOS training to the digitalised training solution. The team are looking to take the Industry / Education 4.0 solution further by removing the JLR Way How To Guides and implementing the training material direct to SuccessFactors using a function within SuccessFactors known as Curriculum. The IPS Team is also examining the results achieved from the current IPS-MOS assessments and looking to improve the How To Guides to provide more information or look at alternative methods of providing information i.e. in picture or diagram form, to suit other learning styles, which may result in an improvement to the understanding of the Systems and Tools and therefore, a decrease in the average number of attempts required to pass the digitised assessments.

5. Conclusion

Due to the COVID19 pandemic of 2020, there has been a need to socially distance as it is one of the most effective ways of minimising transmission of the disease. Therefore, new, innovative methods of training and educating employees within manufacturing needed to be created, utilising technology and an Industry 4.0 mindset.

This research has shown that a digitalised approach to training employees in Lean Manufacturing principles has been effective, not only during the first UK National Lockdown when a number of employees were required to work from home, but also during employees phased return from the UK National Lockdown. The digitalised training of Lean principles removed the need to carry out classroom-based training, providing a socially distanced solution.

In total, 1819 attempts on the digitised training were recorded and 608 (33.4%) attempts were successfully passed on the Lean principles training during the first UK National Lockdown by the employees who were able to work from home. Without this digitised training, there would have been no training available for anyone working from home during this time.

Between March 2020 and the 31st of December 2020, 6137 attempts were made on the digitised training with 1812 or 29.5% attempts successfully passed. This equates to 614 attempts and 181 or 29.5% attempts successfully passed per month on average between March 2020 and the 31st of December 2020. In 2019, the IPS Team completed classroom training to around 50 people per month, on average, across all build and machining halls. Therefore, utilising the digitised training solution has almost quadrupled the IPS Teams' ability

to provide training on Lean principles, whilst also maintaining social distancing measures.

In the company, the SuccessFactors digitised training is utilised for corporate training that needs to be distributed company wide. However, this research has proven that SuccessFactors digitised training can be utilised locally at the individual manufacturing plants. The authors have also started creating and implementing digitised training for the EMC locally for the Operations, Engineering and Quality Departments.

Even with the re-introduction of classroom-based training, the digitalised training can be utilised as a pre-requisite, further strengthening the Lean principles training in the plant. It can also be used as an annual refresher to ensure that the employees are all aware of the Lean principles and any changes to the Systems and Tools which might have been implemented since the classroom-based training was completed. The digitised training approach allows the training to be more accessible to a greater number of employees across the EMC. For those reasons the training will continue to be utilised in the EMC moving forward.

CRedit author statement

Martin McKie: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing-Reviewing and Editing, Visualization, Supervision. Ricky Jones: Formal Analysis, Writing-Reviewing and Editing, Visualization. Julia Miles: Investigation. Ian Jones: Project Administration.

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