The digitalisation and virtual delivery of Lean Six Sigma Teaching in an Irish university during COVID-19

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Abstract. This research discusses how lecturers in an Irish university transferred their classroom-based blended learning Lean Six Sigma modules to online delivery. The transfer from a practical classroom environment to an online classroom needed to be seamless in the students Lean active learning experiences. The output of the paper is to discuss the designing of appropriate delivery methods and practical examples, games, scenarios, exercises in a flipped online classroom. Problem-based learning is ideal for teaching lean manufacturing, driven by a problem-solving culture that values learning as a critical output. The design of a "practical problem based " online Kaizen utilising the virtual classroom as an obeya room enabled students to learn Lean Six Sigma tools and practically deploy the tools. Qualitative and quantitative measures were deployed to assess the success of the transition.

Keywords: Digitalisation, Lean, Online delivery, University teaching, Obeya, Virtual Kaizen; Lean Education; Flipped classroom

1 Introduction

The digital era encourages the use of Information Technology (IT) in the education sector [1]. However, due to the COVID-19 pandemic, most educational institutions across the world have moved their teaching online and put their efforts into preparing online distance education to ensure learning and teaching continued uninterrupted [2]. The COVID-19 pandemic brought significant disruption to classroom-based learning and activities. Before COVID-19, Lean was taught to university students via classroom games and activities and practical exercises. Large classrooms with plenty of wall space for "paper" based exercises and containing several whiteboards meant Lean training could be delivered to up to 30 students at a time in a practical and blended manner. Problem-based learning focuses on small groups using authentic problems to help participants obtain knowledge and problem-solving skills. This approach makes problem-based learning ideal for teaching lean manufacturing, driven by a culture of problem-solving that values learning as one key output of manufacturing production[3].
This blended delivery mode helped replicate core concepts of LSS training the application of brainstorming, aided teamwork and aided replication of a fundamental organisational problem-solving environment [4]. In addition, blended learning can help students assimilate more quickly to online environments [5].

Transferring Lean education online or digitalising is not straightforward. The highly interactive nature of LSS education within the student peer group and with the lecturer or facilitator needed to be replicated. This replication needed to ensure that the quality of learning, the qualitative student learning experience and even the academic quantitative results obtained were not adversely affected. In ramping up the university capacity to teach remotely, schools and colleges took advantage of asynchronous learning, which works best in digital formats. Online teaching should include varied assignments and design student assessments at first to help teachers focus [6].

The goal of this research is a case study on developing a user friendly, virtual learning environment wherein the students studying Lean would be able to apply lean tools in a case study game format in a hypothetical manufacturing facility. The purpose is to educate and acquaint students with real-life problems in an organisation based on real-life scenarios. Furthermore, the students would implement lean tools in a virtual setting, thus fostering the students' development through active learning and improving students' learning, motivation, and retention [7]. This paper explains the main challenges, assignment design, and the integration of various lean tools incorporated in the virtual classroom.

Thus the summary of the research questions are:

- How can Lean Six Sigma education be transferred to the online classroom to emulate the physical classroom?
- How can the quality of learning, understanding and student experience of the methods be assured, applied and measured?
- What were the challenges and the pros and cons of virtual online classroom delivery versus a physical classroom?

2. Literature Review

Lean today has changed from its origin as a manufacturing methodology to an ideology that ties in all aspects of the organisation and can be deployed in services, healthcare, financial organisations. This demands engineers and practitioners with lean, solid basics. Therefore, it is essential to know about the lean tools, but it is even more critical to understand how to apply these tools most effectively [7].

Today's engineering education requires a curriculum that allows students to utilise and learn of the latest technologies [8]. Irrespective of the pros and cons of virtual online delivery, which have been discussed by many authors [9], [10], the COVID -19 pandemic meant the only option available to deliver modules was online.

The online delivery format's perspective does not affect student learning outcomes, dubbed the "no-significant-difference" perspective [11]. However, Gillespie (1998) [12] put forward that online learning tasks should be designed to help learners develop higher-level thinking skills and evaluate their understanding, mediated by sharing ideas and problems with the content using interactive or collaborative online formats.

Research has shown that “flipped” classroom scores higher than a conventional, lecture-oriented set up on the following criteria: student involvement, task orientation, and innovation and promoting collaborative learning [4]. Thus there is a need to structure the learning tasks to fruition of a flipped classroom exercise, albeit if a virtual one. This approach can be taken with Lean teaching as the methodology requires practical tools and skillset application [3].

Problem-based learning (PBL), active learning, blended learning, flipped learning, and Simulation & Gaming are experiential learning formats. These approaches are all conducive to teaching Lean. Moreover, a PBL approach is more involving and enjoyable than more traditional approaches as learning is active[2],[13].

Literature on teaching Lean virtually or in a flipped classroom is not as prevalent as the giant body of research and journals related to online teaching in general. However, the learnings around online teaching methods can most certainly be leveraged somewhat and applied to Lean teaching in a virtual environment. However, there are still many related studies of online Lean education and virtual industry-based Kaizen events [14], [15], [7], [16],[17], with more studies published on lean teaching and virtual kaizen events since the COVID-19 pandemic. In addition, a sense of community is central to student engagement and satisfaction in a virtual classroom, and breakout rooms help develop a sense of community[18].

Simulation has been very much presented as a best practice for online Lean virtual events and teaching[19],[3],[20], [21]. However, the simulation software available may not always be relevant and does not allow tailoring to lecturer designed case studies and applications. In addition, the design of the simulation exercise and practical implementation and learning may take time that is not available. It is also expensive to purchase and develop.

Lean Six Sigma techniques and tools are considered the cornerstones for eliminating waste are thus referred to as "Kaizen building blocks" [22]. A Lean training, approach, deployment, education can begin by implementing basic Lean and Six Sigma techniques and tools such as 5S, Kaizen teams, standardisation and elimination of waste (Muda), unevenness (muri) and overburdeness (Mura) in working processes ([23], [15]). Lean Six Sigma thinking evolves towards more complex techniques and tools that are considered to be part of Lean thinking, such as just-in-time (JIT) manufacturing), Kanban setup, poka-yoke (error-proofing), single minute exchange of dies (SMED), and Hejunka (levelling production) [7]. Given this, the research suggests that learning about Lean within a virtual classroom can aid this learning, application and understanding about LSS.

3. Methodology

3.1 Development of online Lean learning module

This section of the paper describes the main case study Kaizen assignment, which was developed as a series of Lean and Six Sigma exercises that could be carried out in the virtual classroom, which became the online "kaizen" room or "obeya" (Table 1).

The Kaizen room or obeya room, a potent tool for facilitating teamwork and better managing projects, was considered the "control centre" to deploy the Lean training and learning [24].

The students in the university have not worked in a manufacturing environment whatsoever and were not familiar with Lean or operations. However, as postgraduate students, online delivery is more amenable to these learners as they generally have greater self-regulation and acquiring learning strategies and can adjust to online environments relatively quickly[5, 25].

This assignment, or "kaizen" as it was framed, is based on a theoretical company called "ABC Manufacturing" who produce and deliver sandwiches and are arguably a "service" industry also. "Sandwiches" were picked as a product as opposed to "widgets" or other products as they are uncomplicated and straightforward to make, and students are familiar with them and their "components". The Kaizen case study was designed to present the worst-case scenario or demonstrate an ineffective, poorly managed organisation with poor productivity, high defect rates, late deliveries, extensive customer complaints, poor communication, poor leadership and other inefficiencies. The online Kaizen needed to emulate the active and blended classroom learning environment and an organisational environment of brainstorming, huddles, teamwork and practical completion of process maps, value stream maps, cause and effects via collaboration. Lean Engineering Education calls for both content and competency mastery, and this assignment was designed to provide opportunities to demonstrate these competencies. This combination is necessary for professional engineering career success[17].

The case study game given to the students contained information about the company performance and some background concerning key performance indicators (KPI's). In addition, an explanation is given of how orders are received, processed and downloaded onto the manufacturing floor, details of the supply chain procurement process, incoming receiving, warehousing, production, shipping, and delivery. The students carry out the following activities are outlined in Table 1.

Table 1: Lean Principles and Concepts explored and applied within the virtual Kaizen online obeya classroom.

Lean/Six Sigma Tools Utilised and taught and applied in Online Kaizen Classroom.
SMART problem statement The students were given enough information to develop a problem statement and set goals and objectives for the kaizen activity.
Key Performance Indicator (KPI) Scorecard Students were given a suite of data and performance measures related to Productivity, Delivery, Quality and Cost.
Non-Value Add wastes Several Lean wastes are presented within the case study for the student to identify (more than 30 examples of the 8 Lean Wastes were contained therein.
Value Stream Mapping and Takt time Based on the case study information, they were asked to identify non-value wastes and potential areas which could be causing problems. Finally, takt time was to be established based on the VSM and data provided.
Pull and Flow principles. Students were asked to look at the process and ascertain where pull and flow were lacking and where they could be improved.
Check sheets, Histograms, Pareto, Control Charts. Data was provided to enable students to utilise and learn about essential quality management tools.
Poke Yoke an example of process errors in the case study was presented, and students asked to error-proof the process
5S students were given samples of untidiness with the

organisation in the warehouse, production floor, and offices; they were then asked to state how they would carry out a 5S based on their information. They were asked to develop a 5S audit template.
Hejunka students were given examples of inadequate flow and unevenness within the order scheduling process and within the outgoing shipping process and asked to brainstorm how they would improve it using Hejunka to implement evenness.
Cause & Effect diagrams To root cause issues identified throughout the Kaizen, students were encouraged to apply the C&E diagram to 2 problems; 1) Reasons for deliveries taking up to 5 hours and 2) reasons for high defect rates and complaints.
5 Whys Students were asked to utilise and apply the 5 Whys tools to develop a root cause further and identify corrective actions for identified issues within the C&E process.
Future State Value Stream Map Students were asked to brainstorm and design a new future VSM with improvements in flow, pull and waste reduction and new Takt times.
New KPI Scorecard Students estimated how changes and actions implemented had affected the original KPI metrics.
Reflection & Kaizen Closeout Students asked to reflect on Lean and methods and how tools helped.

3.2 The Virtual Obeya Kaizen Room

The virtual learning environment (VLE) platform utilised was Blackboard which is the university VLE of choice as shown in Figure 1. Within the virtual classroom, students were divided into breakout rooms. The breakroom exercises followed a DMAIC problem-solving approach so that each breakout room exercise built on to the previous activity and task. Within the breakout rooms, the lecturer could recreate the teamwork and brainstorming aspects of Lean in the workplace and physical classroom. To evaluate and ensure learning, the lecturer moved between breakout rooms to chat with and advise the students. Each breakout room team had control of the screen and whiteboard, so students could brainstorm and apply Lean tools to aid problem-solving. After each activity, the lecturer would bring the teams back into the virtual classroom, and each group would present their progress. The presentation of progress was essential to ensure that the exercise was understood and provide feedback to the students, and share ideas within the class. The lecturer presented some theory and background to each Lean tool or practice and various Lean principles before commencing with the next breakout room exercise.

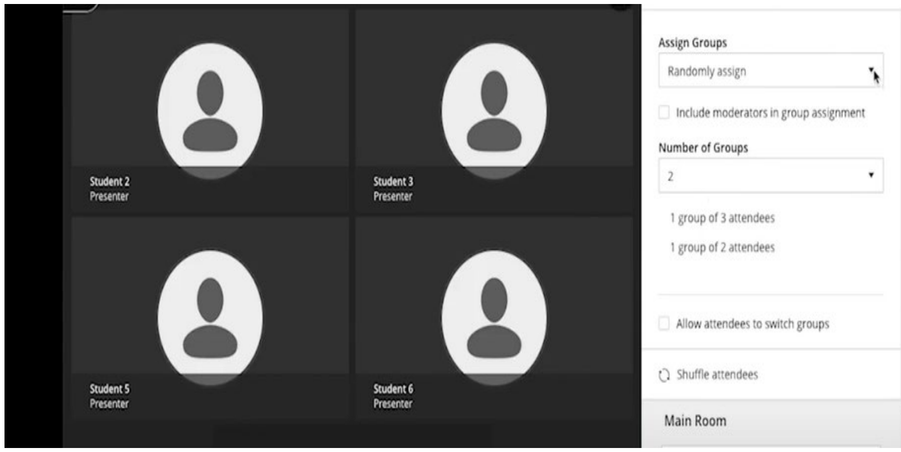


Figure 1: Screenshot of basic online breakout rooms

4.0 Results

In this research, postgraduate students applied Lean Six Sigma tools such as Value Stream Mapping (VSM), 5S, Visual Management, Single Minute Exchange of Dies (SMED), Kanban, Plan-Do-Check-Act (PDCA), DMAIC, process and effect, 5Whys, pores mapping, poke yoke, JIT and Kanban amongst others (Table 2). They developed the project or case study virtual kaizen integrated into teams, as per a problem-based learning, active learning and obeya system situation as if they had been in a flipped physical university classroom. In each instance, the students submitted with their groups (alternating in presenting). This helps provide instruction from the lecturer, validated the learnings, and gives both positive and constructive feedback [26].

Results from the blended learning classroom Lean teaching in previous years were compared qualitatively and quantitatively with the virtual classroom Lean cohorts. Students always performed very highly in the blended flipped classroom kaizen assignments, and the virtual classroom results emulated previous cohorts. Qualitative feedback forms completed by the students measured on a Likert scale were very favourable compared to prior years, which were university campus classroom-based. A satisfaction mean average of 4 out of 5 was achieved in comparing both cohorts. Students have completed some university classroom-based continuous improvements workshops before the COVID-19 lockdown so that we're able to reach the flipped classroom experiences.

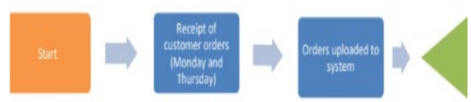
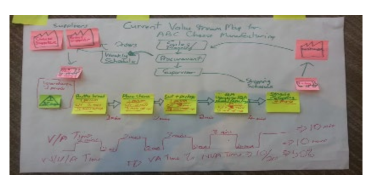
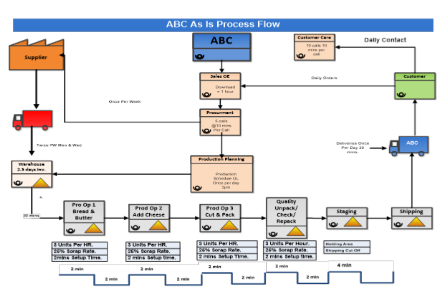
Some of the commentary selected from the students was as follows:

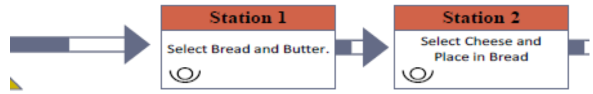
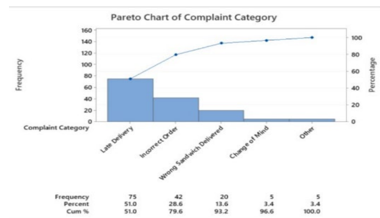
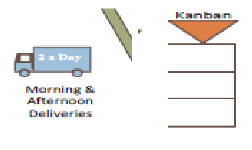
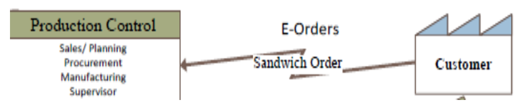
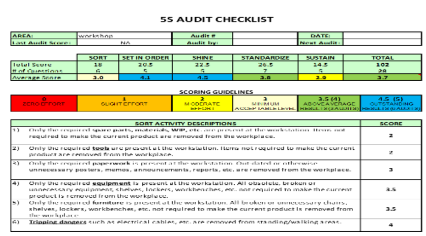
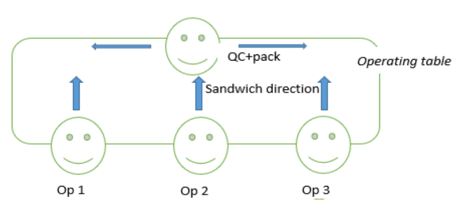
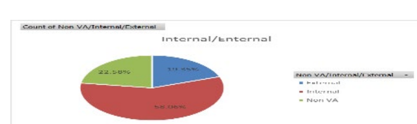
" *I enjoyed how some of us came up with so many different solutions*", "*I enjoyed the scenario -it felt real*", "and "*I didn't feel as if I was in a lecture -as I was busy, active and learning*".

Students also highlighted critical thinking, enjoyability and teamwork interaction. "*Confidence*" was a repeated theme, as was "*I can use these tools*", "*I understand the tools* ", and "*Lean is not hard*".

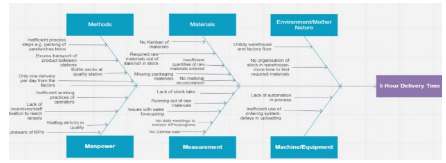
Table 2: How Lean Principles and Concept Learning was applied, demonstrated, shared and reviewed within the virtual Kaizen online obeya classroom

(Note: All screenshot images are taken from examples of online screenshots and uploaded online submissions of student work shared during the online Kaizen)

Lean/Six Sigma Tools Utilised and taught in Online Kaizen Classroom	**Learning demonstrated and deployed in Virtual Classroom BREAKOUT ROOMS**	**Review, Sharing & Feedback in Virtual Classrooms**
SMART problem statement The students were given enough information to develop a problem statement and set goals and objectives for the kaizen activity.	Students collaborate in the online classroom to develop a problem statement and set goals and objectives for the kaizen activity.	From a manufacturing point of view, ABC Sandwich Company's operations team has the capacity to produce 3 units/hour, with a TAKT time of 4 units per hour meaning that they are not meeting customer demand. This LSS project will aim to meet customer demand by reducing process cycle time in manufacturing by 50% from 20 minutes to 10 minutes per sandwich within three months/ by the end of quarter 3. Lecturer & Peer Review in the online classroom
Key Performance Indicator (KPI) Scorecard Students were given a suite of data and performance measures related to Productivity, Delivery, Quality and Cost.	Students collaborated and developed a KPI scorecard based on the information given.	Key Performance Indicator Process Cycle Time Yield Delivery Time Customer Complaints Lecturer & Peer Review in the online classroom
Process Mapping Students were asked to draw a process map based on the steps outlined in the case study.	Students collaborated and designed a "Current" Process Flow.	 Lecturer & Peer Review in the online classroom
Non-Value Add wastes Several Lean wastes are presented within the case study for the student to identify (more than 30 examples of the 8 Lean Wastes were contained therein.	Students brainstormed and presented all of the 8th waste types observed in the case study.	Waste / Example Transportation: • Time and effort spent transporting product between three stations in the manufacture of one unit but do not add value to the customer • Over handling of materials leading to damage of product Inventory: • Raw materials that are not used by their expiry date Lecturer & Peer Review in the online classroom
Value Stream Mapping and Takt time Based on the case study information, the students were asked to identify non-value wastes and potential areas which could be causing problems. Finally, takt time was to be established based on the VSM and data provided.	The students worked on creating a VSM within the classroom breakout rooms utilising a virtual whiteboard. Students presented a virtual VSM and takt time calculations.	  Lecturer & Peer Review in the online classroom

Pull and Flow principles. Students were asked to look at the process and ascertain where pull and flow were lacking and where they could be improved.	Students brainstormed idea on pull and flow improvement and presented in the online classroom.	 Lecturer & Peer Review in the online classroom
Check sheets, Histograms, Pareto, Control Charts. Data was provided to enable students to utilise and learn about essential quality management tools.	Students presented examples of tool applications and learnings.	
JIT & Kanban Just in Time and Kanban explained, opportunities were presented within the case study to explain the theory.	Students brainstormed where Kanban and JIT may be utilised in the case study.	 Lecturer & Peer Review in the online classroom
Poke Yoke an example of process errors in the case study was presented, and students asked to error-proof the process	Students gave examples of error proofing about the issues presented	 Elimination of manual order entry – real-time E-orders  Lecturer & Peer Review in the online classroom
5S Students were given examples of untidiness with the organisation in the warehouse, production floor and offices; they were then asked to state how they would carry out a 5S based on the information they had. Finally, they were asked to develop a 5S audit template.	Students presented a 5S program and 5S audit.	 Lecturer & Peer Review in the online classroom
Hejunka Students were given examples of inadequate flow and unevenness within the order scheduling process and within the outgoing shipping process and asked to brainstorm how they would improve it using Hejunka to implement evenness.	Students presented where Hejunka was required and how it could be utilised.	 Lecturer & Peer Review in the online classroom
SMED Students give examples of slow turnarounds and, in line with 5S examples, brainstormed	Students presented SMED opportunities in the customer ordering processes and within the production line.	

<table>
<tr><td>where SMED could be applied.</td><td></td><td>Lecturer & Peer Review in the online classroom</td></tr>
<tr><td>Cause & Effect diagrams

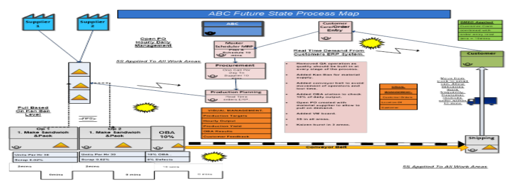
To root cause issues identified throughout the Kaizen, students were encouraged to apply the C&E diagram to 2 problems; 1) Reasons for deliveries taking up to 5 hours and 2) reasons for high defect rates and complaints.</td><td>Students presented C&E diagrams and how they applied cause screening to the issues identified in the cause and effect and prioritised the issues based on a high, medium, and low potential for causing problems and fixing.</td><td>

Lecturer & Peer Review in the online classroom</td></tr>
<tr><td>5 Whys

Students were asked to utilise and apply the 5 Whys tools to develop a root cause further and identify corrective actions for identified issues within the C&E process.</td><td>5 Whys scenarios presented for various root causes</td><td>1. Why are the box labels being put on incorrectly?
Operators placing incorrect label on product boxes i.e. mixing up label for secondary and tertiary packaging
2. Why are operators mislabeling boxes?
They are mixing up the labels that are required for each stage of the packaging process
3. Why are they mixing up labels?
Labels are not always legible and can be difficult to read.
4. Why?
Issues with printing equipment and staff skills using the equipment
5. Why?
Staff have not received adequate training and machines are not being maintained adequately

Solution: Staff training and starting a routing maintenance schedule for equipment including label printer

Lecturer & Peer Review in the online classroom</td></tr>
<tr><td>Future State Value Stream Map

Students were asked to brainstorm and design a new future VSM with improvements in flow, pull and waste reduction and new Takt times.</td><td>Future VSM with improvements presented</td><td>

Lecturer & Peer Review in the online classroom</td></tr>
<tr><td>New KPI Scorecard

Students estimated how changes and actions implemented had affected the original KPI metrics.</td><td>New KPI scorecard presented with justification for reducing costs, quality defects, improved delivery, etc.</td><td>Table 7. Estimated score card for target KPIs 6 months after completion of LSS project<table><tr><th>Process/KPI</th><th>Improvements Made</th><th>Before</th><th>Results</th></tr><tr><td>Process Cycle Time</td><td>- Changes to line layout
- Reduction of production Stations from 3 to 2
- One-piece flow</td><td>20 minutes per unit and 2 minutes set up time/unit</td><td>10 minutes/unit and 1 minute line clearance between units</td></tr></table>Lecturer & Peer Review in the online classroom</td></tr>
<tr><td>Reflection & Kaizen Closeout

Students asked to reflect on Lean and methods and how tools helped.</td><td>Reflection discussion and Kaizen close out held. Congratulations to Team.</td><td><table><tr><th colspan="2">Improvements from Lean Principles Adopted:</th></tr><tr><th>Before</th><th>After</th></tr><tr><td>• Warehouse housed 2.5 days of inventory and staff were not aware when resources where running low.
• Parts getting mixed up and individuals having difficulty finding parts.
• Throughout ABC areas are generally untidy, non-essential equipment is getting in the way of production and some individuals and items are difficult to locate because of a lack of signage and</td><td>• <u>Kanban</u> system helps eliminate the need for a warehouse as items remain stocked on the floor by the supplier This system means that the produce being used for the product is consistently fresh.
• <u>Using 5S principles</u> organise storage and wall organisers to help operating staff to keep their parts and equipment organised.
• <u>5 S's</u> practice disposes of all non-essential items and equipment. Signage and labelling is used throughout to indicate locations of staff members or items</td></tr></table>Lecturer & Peer Review in the online classroom</td></tr>
</table>

5.0 Discussion & Conclusion

The effectiveness of the virtual delivery training was confirmed through feedback from over 100 learners. The research results aim to demonstrate the learning to practical examples and scenario learning due to the relatively simple design of the problem under study. The course evaluations of the learners rated the course 4.5 out of 5 stars. The quality and standard of the delivery ensured the learning was appliable, with 98% of learners reporting that they will apply the new skills learned and felt competent in using Lean Six Sigma tools and applications.

In any form of education, it is important to use a suitable learning environment for the intended purpose of the training, the education, and for the participant group and online to provide that environment if designed correctly. Particularly with Lean education, where the is a suite of tools and techniques associated with the methodology, the above statement is true.

Lean students are the future professionals of organisations, and their learning must be aligned with industry and society needs. Being taught in Lean education, in the form proposed by this paper, students will develop competencies and will have the ability to meet problem-solving and tool applications to a high degree of complexity and application. While simulation type software and Virtual Reality (VR) would be helpful and enhance future online lean, learning was a limitation in terms of time to include in this case study[21]. The author would like to expand the usage of these technologies for future online lean virtual education. An ultimate aim would be to simulate a complete virtual manufacturing process. This would give the students even more insight into the dependence of lean (especially JIT) on the supply chain and logistics.

References

1. Junus, K., Santoso, H.B., Putra, P.O.H., Gandhi, A., Siswantining, T.: Lecturer Readiness for Online Classes during the Pandemic: A Survey Research. Education Sciences. 11, 139 (2021). https://doi.org/10.3390/educsci11030139.
2. Tortorella, G.L., Narayanamurthy, G., Sunder M, V., Cauchick-Miguel, P.A.: Operations Management teaching practices and information technologies adoption in emerging economies during COVID-19 outbreak. Technological Forecasting and Social Change. 171, 120996 (2021). https://doi.org/10.1016/j.techfore.2021.120996.
3. Badurdeen, F., Marksberry, P., Hall, A., Gregory, B.: Teaching Lean Manufacturing With Simulations and Games: A Survey and Future Directions. Simulation & Gaming. 41, 465–486 (2010). https://doi.org/10.1177/1046878109334331.
4. Prashar, A.: Assessing the Flipped Classroom in Operations Management: A Pilot Study. Journal of Education for Business. 90, 126–138 (2015). https://doi.org/10.1080/08832323.2015.1007904.
5. Arbaugh, J.B.: What Might Online Delivery Teach Us About Blended Management Education? Prior Perspectives and Future Directions. Journal of Management Education. 38, 784–817 (2014). https://doi.org/10.1177/1052562914534244.
6. Daniel, S.J.: Education and the COVID-19 pandemic. Prospects. 49, 91–96 (2020). https://doi.org/10.1007/s11125-020-09464-3.
7. Gadre, A., Cudney, E., Corns, S.: Model Development of a Virtual Learning Environment to Enhance Lean Education. Procedia Computer Science. 6, 100–105 (2011). https://doi.org/10.1016/j.procs.2011.08.020.
8. The National Academic Press: Front Matter | Educating the Engineer of 2020: Adapting Engineering Education to the New Century | The National Academies Press. The National Academies Press, Washington DC (2005).
9. Daft, R.L., Lengel, R.H.: Organizational Information Requirements, Media Richness and Structural Design. Management Science. (1986). https://doi.org/10.1287/mnsc.32.5.554.
10. Kock, N., Verville, J., Garza, V.: Media Naturalness and Online Learning: Findings Supporting Both the Significant- and No-Significant-Difference Perspectives. Decision Sciences Journal of Innovative Education. 5, 333–355 (2007). https://doi.org/10.1111/j.1540-4609.2007.00144.x.
11. Summers, J.J., Waigandt, A., Whittaker, T.A.: A Comparison of Student Achievement and Satisfaction in an Online Versus a Traditional Face-to-Face Statistics Class. Innovative Higher Education. 29, 233–250 (2005). https://doi.org/10.1007/s10755-005-1938-x.
12. Gillespie, F.: Instructional Design for the New Technologies. New Directions for Teaching and Learning. (1998).
13. Tortorella, G, Cauchick-Miguel, P.A.: Combining traditional teaching methods and PBL for teaching and learning of lean manufacturing. IFAC-PapersOnLine. 51, 915–920 (2018). https://doi.org/10.1016/j.ifacol.2018.08.465.
14. Venegas, C: How to have a successful office kaizen: Co-located, distributed, or virtual (Presentation) - ProQuest. In: IIE Annual Conference proceedings (2007).
15. Suárez-Barraza, M.F., Ramis-Pujol, J.: Implementation of Lean-Kaizen in the human resource service process: A case study in a Mexican public service organisation. Journal of Manufacturing Technology Management. 21, 388–410 (2010). https://doi.org/10.1108/17410381011024359.
16. Alves, A.C., Flumerfelt, S., Moreira, F., Leão, C.P.: Effective Tools to Learn Lean Thinking and Gather Together Academic and Practice Communities. Presented at the ASME 2017 International Mechanical Engineering Congress and Exposition January 10 (2018). https://doi.org/10.1115/IMECE2017-71339.
17. Flumerfelt , S, Kahlen , F.J ., Alves , A., Siriban-Manalang, A: The future state of content & competency-based engineering education: Lean Engineering Education. In: Lean Engineering Education. ASME Press (2015).
18. Berry, S.: ERIC - EJ1210946 - Teaching to Connect: Community-Building Strategies for the Virtual Classroom, Online Learning, 2019-Mar. Online Learning. 23, 164–183 (2019).
19. Kuriger, G.W., Wan, H., Mirehei, S.M., Tamma, S., Chen, F.F.: A Web-Based Lean Simulation Game for Office Operations: Training the Other Side of a Lean Enterprise. Simulation & Gaming. 41, 487–510 (2010). https://doi.org/10.1177/1046878109334945.
20. Verma - Deliverable for Phase-0 NSRP- ASE – 0301-1.pdf, https://nsrp.org/wp-content/uploads/2015/10/Deliverable-2004-323-Lean_Enterprise_Simulation_Final_Report-Old_Dominion_University.pdf.
21. Wan, H., Chen, F.F., Saygin, C.: Simulation and training for lean implementation using web-based technology. International Journal of Services Operations and Informatics. 3, 1–14 (2008).

https://doi.org/10.1504/IJSOI.2008.017701.
22. Imai, M: Kaizen - the key to Japanese competitive success. Random House Business Division., New York (1989).
23. Byrne, B., McDermott, O., Noonan, J.: Applying Lean Six Sigma Methodology to a Pharmaceutical Manufacturing Facility: A Case Study. Processes. 9, (2021). https://doi.org/10.3390/pr9030550.
24. Priolo, R: What is an Obeya?, https://planet-lean.com/what-is-obeya/, last accessed 2021/07/07.
25. Arbaugh, R.B, Hwang, A: Does "teaching presence" exist in online MBA courses? - Learning & Technology Library (LearnTechLib). Internet & Higher Education. 9, (2006).