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Using Simulation software Rockwell Arena for effective teaching of Value Stream Mapping in Undergraduate Lean Six Sigma Class.

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Abstract

Lean Six Sigma (LSS) has become an important topic these days in continuous process improvement. LSS is a combination of Lean principles of waste reduction and Six sigma methods of variation reduction. Combined, Lean Six Sigma becomes an immensely powerful tool for process improvement in today's highly competitive markets wherein quality, productivity and cost are all important for customer satisfaction. A value stream map (VSM) is one of the most important and the most complex tools in lean.

Traditional teaching of VSM in undergraduate Lean Six Sigma class is achieved by firstly mapping the "As Is" state of the process and then converting the "As Is" VSM into a "To be" VSM. This is done by applying lean tools of Kanban, pull system and continuous flow. Since it involves many tools and requires mathematical formulations, it has demonstrated lower student learning outcomes. In this study, we have discussed a new instructional strategy of using simulation software 'Rockwell Arena' to enable effective student learning in class. A simulation of "As Is" state VSM of a manufacturing process is prepared in Arena and displayed in class after completing traditional teaching of Value stream mapping. Further, students suggest and discuss modifications to "As Is" state VSM in Arena Simulation, eventually forming the "To be" VSM of the process. To encourage student participation in class, instructional techniques like think, pair, share are used wherein students are paired in groups to think about a problem and later share their findings with the class.

A student questionnaire comparing student learning before and after instruction using Arena simulation is compiled. It is clear from data that student learning is enhanced with Arena simulation for teaching Value Stream Mapping in undergraduate Lean Six Sigma class.

Keywords: Simulation software, Rockwell Arena, Value Stream Mapping, Lean Six Sigma.

Introduction

Lean Six Sigma (LSS) is a management methodology that combines Lean principles and Six Sigma techniques to improve performance, reduce waste, and enhance efficiency in various processes. Lean Six Sigma is widely used in various industries, including manufacturing, healthcare, finance, and services, to achieve operational excellence and continuous improvement.

Value Stream Mapping (VSM) is a key tool used in Lean methodology, specifically within the context of Lean manufacturing and service industries. It is a visual representation of the entire process of delivering a product or service from the beginning to the end. The purpose of value stream mapping is to identify and eliminate waste in the process and improve overall efficiency.

Lean six sigma involves many tools and most of these tools can be analyzed using Statistical software’s like Minitab and SigmaXL. These software’s have inbuilt functions that take user data and directly display results, thus minimizing efforts and aiding the user in data analysis. But Value stream mapping is one such tool under lean manufacturing that does not have any software to do its work. In VSM you first create a current state map of the process and then improve this map using several lean tools like, Kanban, pull, flow, cell design etc., to convert this map into an improvised future state map.

Arena Simulation Software developed by Rockwell Automation can be used for this purpose. Arena is a powerful simulation tool used for modeling and analyzing complex business processes and systems. It is widely used in various industries such as manufacturing, logistics, healthcare, and services to optimize processes, improve efficiency, and make informed decisions.

Literature Review

Various applications have shown that we require simulation to find and study factors which could not be seen by using lean alone according to Marvel & Standridge [9]. To develop a future state value stream map from the current state map requires elimination of non-value adding components. Elimination of certain components may seem like an obvious improvement at the first look but may adversely affect certain other performance parameters. Thus, realizing to be cautious when working with value stream mapping, because it is not just about making changes, but also about making the right kind of changes as mentioned by Harris & Rother [10]. As mentioned by Gullander and Solding [4], there are some weaknesses related to using Simulation or Value Stream Mapping, alone, to analyze and improve the performance of any manufacturing system. Hence, it is necessary to embed these two important tools into each other, such that the combination of these two can replicate the real-life situation of our manufacturing system as well as leave sufficient room to introduce variability and randomness into various performance parameters of the entire system. A proper gel of these two techniques helps us to keep the system in dynamic motion, while we study the effects of randomly occurring events on the overall system. Simulation modelling and analysis is conducted to gain insight into these complex systems, testing new operating or resource policies and new concepts or systems before implementing them as per Chun [2], and last but not the least, gathering information and knowledge without disturbing the actual system as mentioned by Mourtzis, Doukas, and Bernidak [8].

Terkaj [11] presents an approach where an ontology-based virtual factory is continuously integrated with the real plant. The digital object is used to conduct simulations, aimed at understanding in advance the impact of possible decisions on production and maintenance. Goodall [3] developed a data-driven simulation approach for remanufacturing operations, characterized by data coming from digital manufacturing systems. In this case, the simulation serves to support improvements in the real system, based on the results obtained in the digital counterpart. Zhou [12] propose a scheduling method based on dynamic data-driven simulation to improve the performance of a manufacturing system. The designed approach is tested through a case study on numerical control machining in the domain of cloud manufacturing, and the results demonstrate its goodness. The reader is referred to some comprehensive literature reviews for other simulation-driven approaches. [6][13][1][5]

There is evidence of many researchers using simulation software's to demonstrate lean manufacturing scenarios. A comparative study of teaching lean manufacturing via hands-on and computer aided simulation by Tseng [14] provided value added and non-value-added times for analysis of improvements. Tseng [14] just barely touched on value stream mapping but showed other lean tools like 5S, one piece flow, poka-yoke, and total productive maintenance through simulations. Hence, this is the first attempt to integrate Arena Simulation for teaching value stream mapping in a lean six sigma class.

Value Stream Mapping:

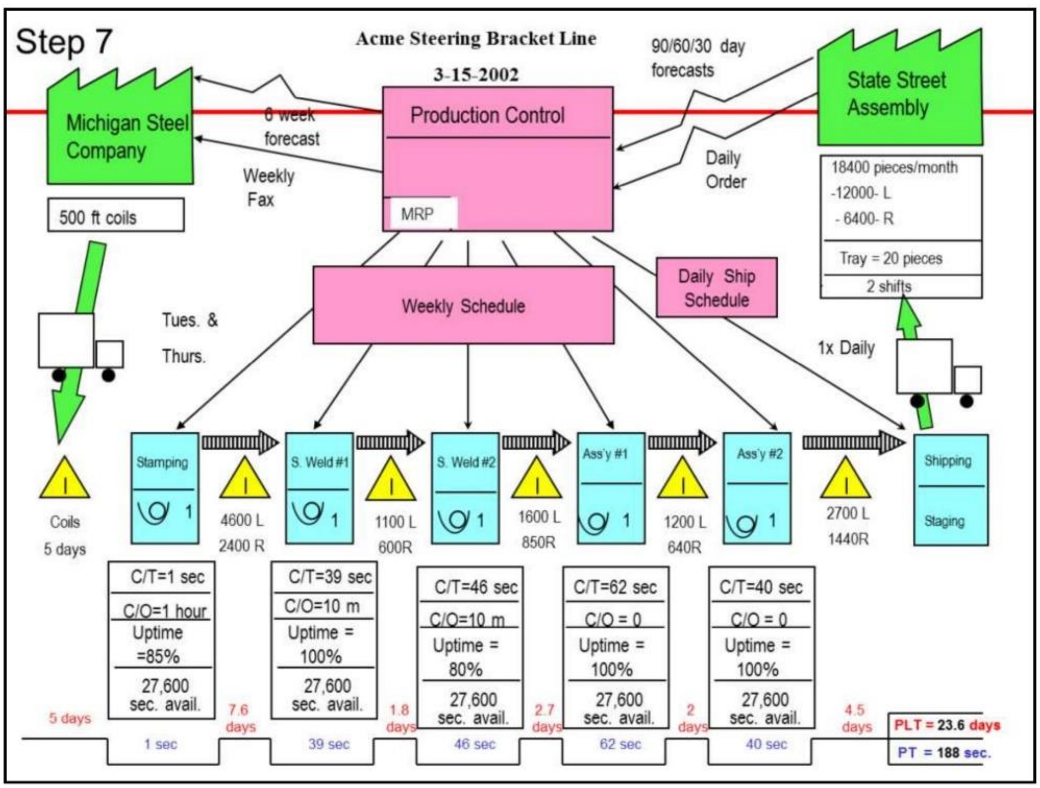


Figure 1: Current State "As Is" Value Stream Map [7]

Value stream mapping originated in the Toyota Production System and has been widely adopted in manufacturing and various industries beyond manufacturing. As shown in figure 1, the current state value stream map is developed by first defining the boundaries of the value stream. This includes identifying the starting point (where the raw materials or information enter the process) and the endpoint (where the finished product or service reaches the customer). Then the current state is mapped, it involves creating a visual representation (often using flowcharts or diagrams) of all the steps, processes, and activities involved in the current state of the value stream. This includes both value-adding activities (those that directly contribute to meeting customer needs) and non-value-adding activities (such as waiting, rework, or unnecessary processing).

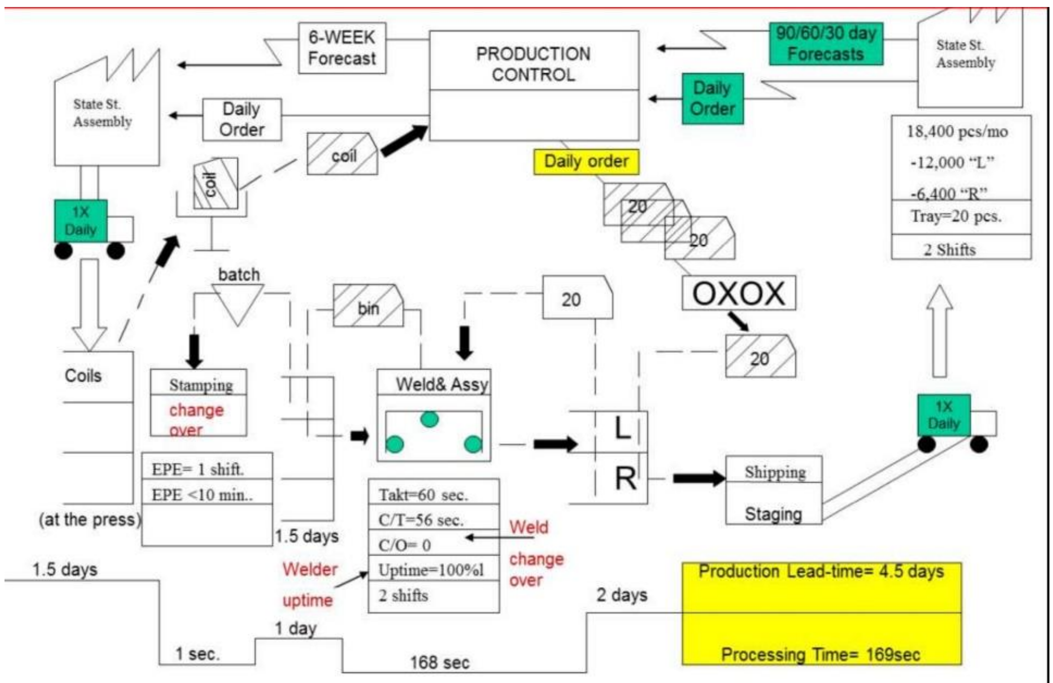
1. 

Figure 2: Future State "To be" Value Stream Map [7]

Once the current state map is complete, the team analyzes it to identify bottlenecks, inefficiencies, and areas for improvement. This analysis may involve calculating cycle times, lead times, and other performance metrics. Based on the analysis of the current state, the team then develops a vision for the future state of the value stream. This involves eliminating waste, reducing lead times, and improving overall efficiency and effectiveness. With the future state in mind, the team develops a plan for implementing changes and improvements. This plan may include specific initiatives, projects, or Kaizen events aimed at addressing the identified opportunities. Once the action plan is developed, the team begins implementing the proposed changes. This may involve reorganizing processes, redesigning workflows, implementing new technologies, or training employees. Throughout the implementation process, the team continuously measures and monitors key performance indicators to assess progress towards the desired future state as shown in figure 2.

The Problem:

In value stream mapping to convert a “as Is” VSM as shown in figure 1, into a “to be” VSM as shown in figure 2, students need to apply various lean manufacturing techniques of kanban, batch size, one piece flow, supermarket pull, push production, Cell design etc. Some of the important aspects in manufacturing like bottleneck process and cell design are difficult for students to visualize. Also, when introducing kanban pull system, it is difficult to analyze the kanban size and batch size for efficient processing. These problems demand a newer method like simulation to assist students in making these decisions and aiding them in developing the future state map.

The Solution:

Using Rockwell Arena as aid for teaching Value Stream Mapping in class: To create a value stream map using Arena simulation software, you can follow these general steps:

1. **Define the Process**: Clearly define the process you want to map out. This could be a manufacturing process, service process, or any other workflow.
2. **Model the Process in Arena**: Use Arena simulation software to create a model of the process. This involves defining entities, attributes, resources, and logic that represent the real-world process accurately.
3. **Collect Data**: Gather data on the process you are modeling. This could include cycle times, lead times, work in progress (WIP), and other relevant metrics.
4. **Run the Simulation**: Run the simulation in Arena to simulate the flow of entities through the process over time. Make sure to set appropriate parameters for the simulation, such as arrival rates, processing times, and resource capacities.
5. **Collect Output Data**: Once the simulation is complete, collect data on key performance indicators (KPIs) such as throughput, cycle time, and resource utilization.
6. **Analyze Results**: Analyze the output data from the simulation to identify areas for improvement in the process. Look for bottlenecks, excessive WIP, and other inefficiencies.
7. **Create the Value Stream Map**: Based on the insights gained from the simulation, create a value stream map using standard symbols and notation. Include information such as process steps, cycle times, inventory levels, and flow of materials or information.
8. **Identify Opportunities for Improvement**: Use the value stream map to identify opportunities for improvement in the process. This could involve streamlining workflows, reallocating resources, or implementing innovative technologies or practices. Monitor the impact of these changes on key metrics and iterate, as necessary.

By following these steps, you can use Arena simulation software to create a value stream map and improve the performance of your processes.

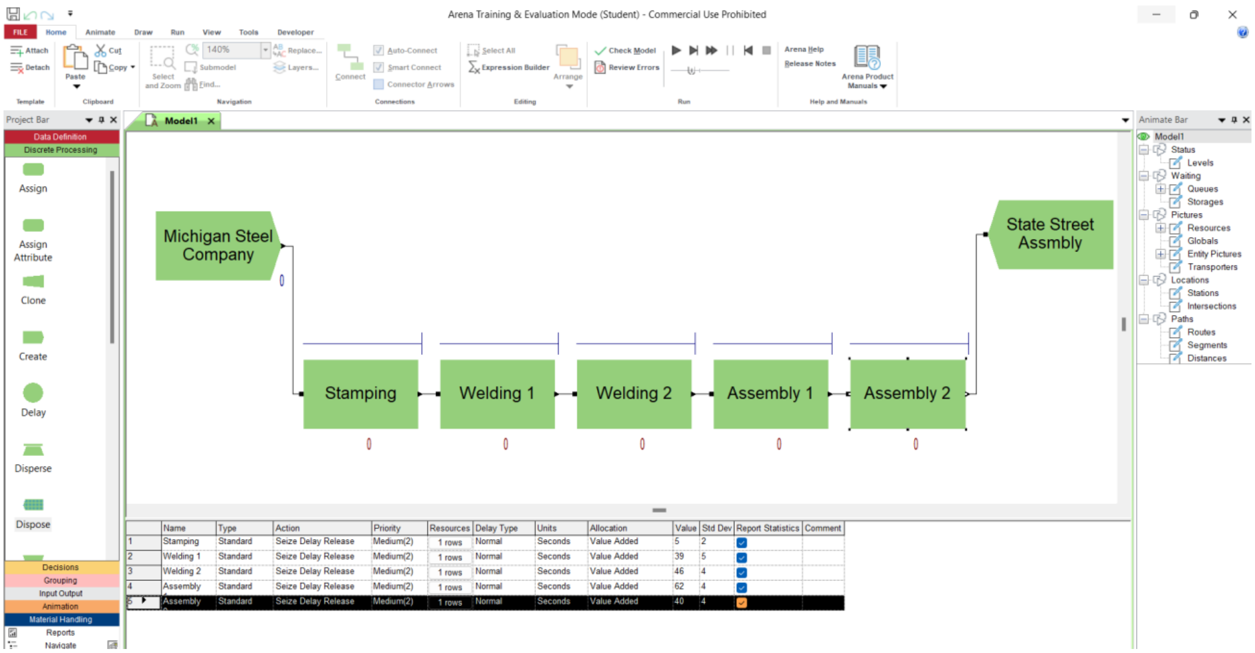


Figure 3*: Rockwell Arena Simulation for the above ACME Stamping operation.*

Figure 3. shows Rockwell Arena modeling of the industrial process shown in figure 1. Here the customer and supplier are the boundaries or end points of the value chain. The individual processes of stamping, welding 1, welding 2, assembly 1 and assembly 2 having cycle times of 1, 39, 46, 62 and 40 seconds, respectively are created in Arena.

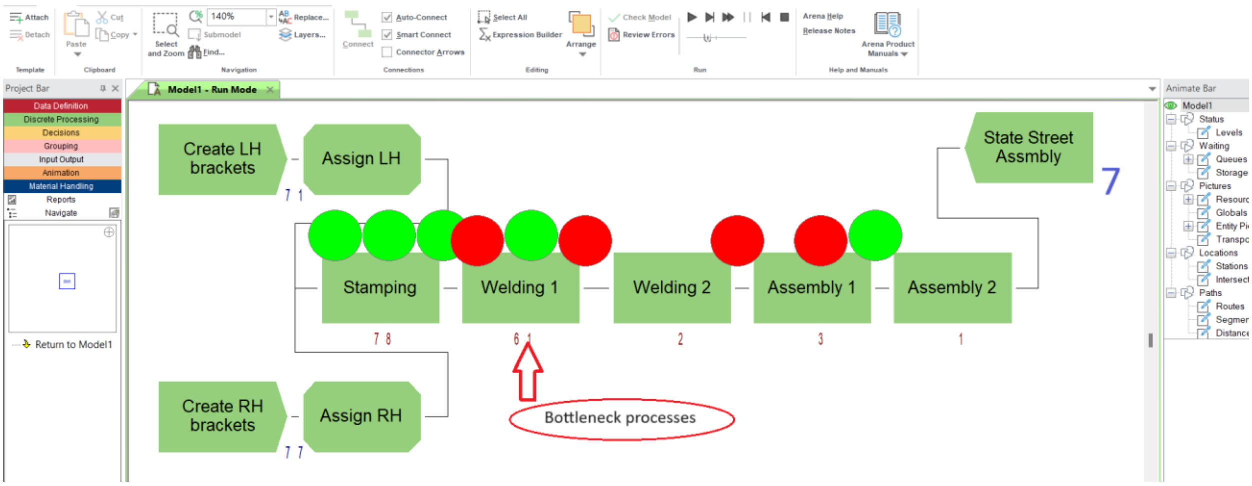


Figure 4*: Arena Simulation showing bottleneck processes.*

The simulation in figure 3. is modified to incorporate LH (left hand) and RH (right hand) brackets and is shown in figure 4. Here, the bottleneck processes where inventory gets built up are clearly seen. These processes need to be modified such that each individual process cycle time is below the takt time and there is minimum difference between the cycle times of individual process. This is possible with batch processing and kanban supermarket pull system with unit cells.

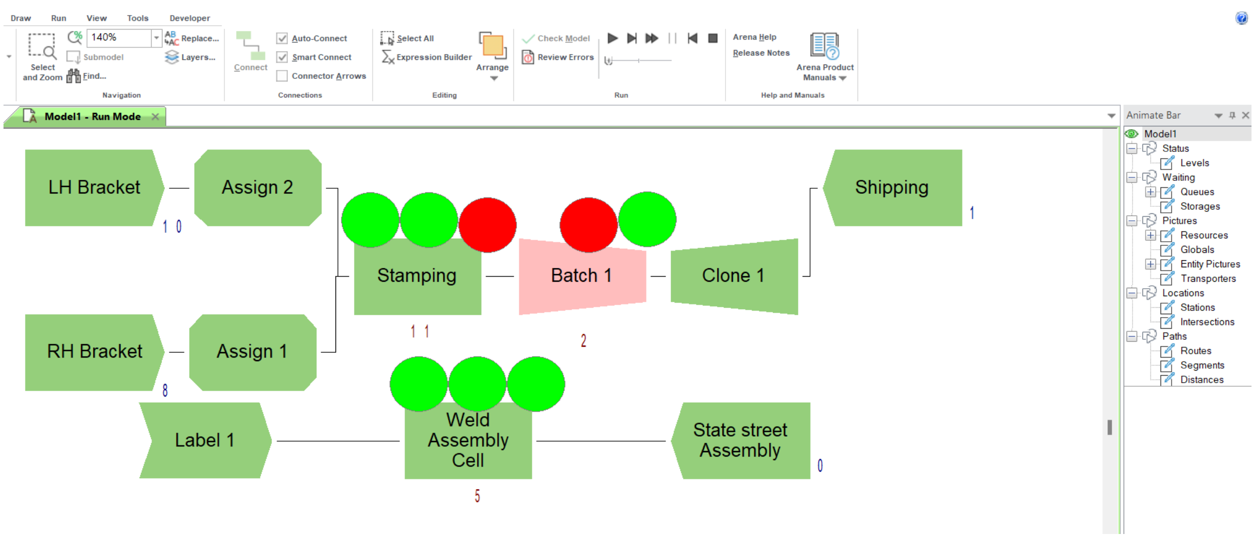


Figure 5*: Arena Simulation showing batch manufacturing.*

This process is further modified to include a weld/assembly cell as shown in figure 5. Earlier, each welding and assembly station had one operator each, making it 4 operators. The cycle times of each operator compared to the takt time of 60 seconds, demanded for operator load balancing. So, the individual welding and assembly stations are combined to form a weld/assembly cell with three operators. This releases one operator to do some other work. This is one more step towards continuous improvement from current state VSM to future state VSM. Then, since stamping only takes one second per part, batch manufacturing is introduced so that there is little inventory buildup at the weld/assembly cell.

To validate this claim, at first, students were taught value stream mapping without using Arena Simulation. Later, while teaching using a classroom projector, the instructor created Arena Simulation models for the processes being taught and simultaneously, rather interactively improved the process with feedback from the students. Thus, creating an improved process that showed the future state value stream map.

A student survey was conducted with a class of 30 students to examine the effectiveness of using Arena simulation for teaching value stream mapping to undergraduate students. Below is the student questionnaire:

1. Did this lecture help you understand the fundamental concepts of value stream mapping?
2. Does the course give you the confidence to do more advanced work in VSM?
3. Do you believe that what has been asked to learn in this course is important and practical?
4. Are you comfortable to do a “To be” VSM map from an “As Is” map?
5. Does the Arena simulation aid you in applying your knowledge to develop a “To be” VSM map?
6. Was the class material provided to you helpful?
7. Did Arena simulation improve the teaching environment in the class and help in better learning of value stream mapping?
8. Were you confident to do a “To be” VSM map from an “As Is” map before using Arena simulation.
9. Are you confident to do a “To be” VSM map from an “As Is” map after using Arena simulation.
10. Would you recommend this course to other students?

Rating scale: 0 – N/A, 1 - Strongly Disagree, 2 - Disagree, 3 – Agree, 4 – Strongly Agree.

Student feedback ‘before’ using Arena and ‘after’ using Arena:

Student Questionnaire	Before	After
1. Did this lecture help you understand the fundamental concepts of value stream mapping?	2.833	3.433
2. Does the course give you the confidence to do more advanced work in VSM?	2.800	3.467
3. Do you believe that what has been asked to learn in this course is important and practical?	3.533	3.233
4. Are you comfortable to do a “To be” VSM map from an “As Is” map?	1.867	3.467
5. Does the Arena simulation aid you in applying your knowledge to develop a “To be” VSM map?	N/A	3.133
6. Was the class material provided to you helpful?	1.933	2.733
7. Did Arena simulation improve the teaching environment in the class and help in better learning of value stream mapping?	N/A	2.967
8. Were you confident to do a “To be” VSM map from an “As Is” map before using Arena simulation.	1.867	N/A
9. Are you confident to do a “To be” VSM map from an “As Is” map after using Arena simulation.	N/A	3.500
10. Would you recommend this course to other students?	1.633	3.333
Total Average score	1.647	2.927

Table 1: Student Questionnaire for before and after using Arena Simulation

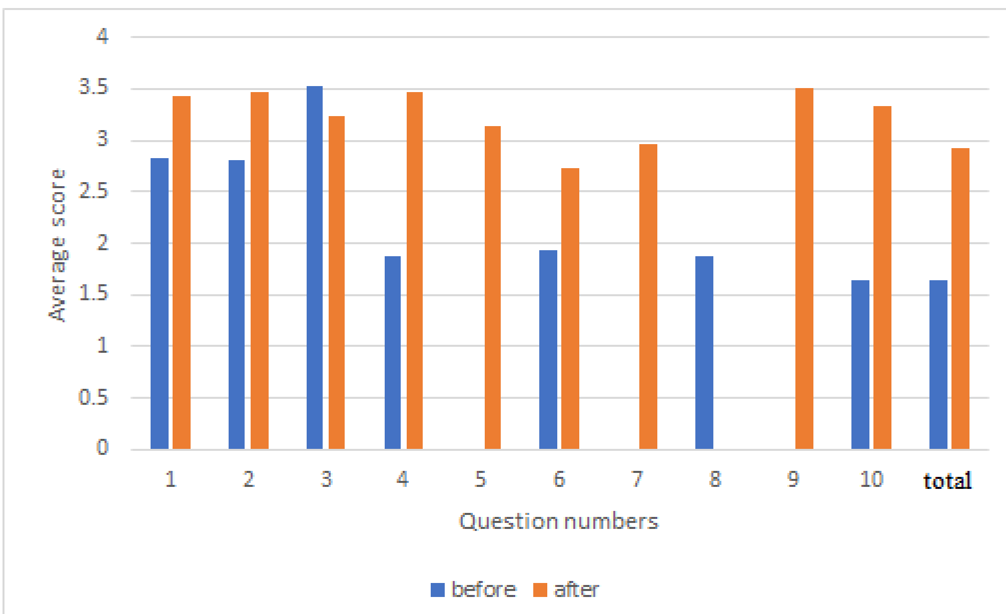


Figure 6: Histogram comparing before and after values.

Table 1. and figure 6. shows student feedback. It indicated that before using Arena Simulation students were almost uncertain about creating a future state map. Students could understand various principles of kanban, batch size and supermarket pull/push but they could not apply them to develop a future state value stream map. Most of the students indicated that after using Arena simulation they could ‘get the right numbers’ for kanban size and batch size. In general students agreed that using Arena simulation enhances their ability to develop a future state VSM from the

current state. The before using Arena score for the above survey totaled to average 1.647 out of 4.0 for a class of 30 students, whereas the score totaled 2.927 after using Arena simulation.

It can be clearly seen that there is an overall improvement in student learning with respect to fundamental concepts, class material, and comfort of drawing a 'To be' VSM after using Arena Simulation. Also, questions 8 and 9 directly compare the before and after using Arena simulation. The score averages to 1.867 before using Arena and 3.5 after. That is a significant improvement in student confidence to do a 'To be' VSM map from an 'As is' map after using Arena Simulation.

before'	
Mean	1.8667
Standard Error	0.1148
Median	2.0000
Mode	2.0000
Standard Deviation	0.6288
Sample Variance	0.3954
Kurtosis	-0.3207
Skewness	0.0977
Range	2.0000
Minimum	1.0000
Maximum	3.0000
Sum	56.0000
Count	30.0000
Confidence Level(95.0%)	0.2348

after'	
Mean	3.4667
Standard Error	0.1496
Median	4.0000
Mode	4.0000
Standard Deviation	0.8193
Sample Variance	0.6713
Kurtosis	1.6306
Skewness	-1.4982
Range	3.0000
Minimum	1.0000
Maximum	4.0000
Sum	104.0000
Count	30.0000
Confidence Level(95.0%)	0.3059

Figure 7: Student questionnaire question 4 'Before' and 'After' descriptive statistics.

Further data analysis is conducted on question 4, "are you comfortable to do a 'To be' VSM map from an 'As Is' map?" This showed a standard deviation of 0.6288 for 'before' using arena and a standard deviation of 0.8193 for 'after' using arena. This shows us that there is only a slight difference of about 0.2 between 'before' and 'after' values indicating good scores with centered mean values and very little standard deviation. Thus, we can conclude that Arena simulation helps students in better understanding of value stream mapping and boosts their confidence in creating a future state value stream map.

Conclusion:

In conclusion, it can be clearly stated that Rockwell Arena Simulation helps students significantly in visualizing manufacturing scenario to be able to successfully implement lean techniques of kanban, cell design, supermarket pull/push to create a future state value stream map. It boosts their confidence to work out other manufacturing scenarios and create a 'To be' VSM for these layouts. In general, Arena simulation makes students comfortable and confident at the same time, to tackle this complex task of creating a 'To be' VSM from an 'As is' VSM.

Future Scope

In the coming semesters the author plans to embed 9 credit hours of teaching 'Rockwell Arena Simulation' into this 45-credit hour Lean Six Sigma class. The author believes that this will further enhance student learning of value stream mapping and improve the class dynamics since this class has two sections, lean, that is more on theory and six sigma, which is more on statistics. Having 9 credit hours for teaching simulation will 'gamify' this topic of value stream mapping and students will learn how to simulate manufacturing processes. This simulation topic not covered under any other undergraduate Industrial Technology classes will benefit students and increase the overall student ratings for this class.

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