A Framework To Implement Varied Learning Environment Using Team Based Learning - Pyramid Hologram To Increase The Learning Outcome In Lean Training

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To my mother and sister, without them I shall not have reached this position

To Shruti and Anuradha for providing constant financial and emotional support

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Abstract

The failure of Lean efforts can largely be attributed to the failure of organizations to prepare their employees for Lean implementation. Employees are provided with formal training that uses educational videos and classroom lectures. These videos and lectures are individual-oriented and do not engage employees by way of active participation. This indicates the need for learning environments which augment the formal experience to improve employee engagement in training. This research proposes a varied learning environment with the help of Team-Based Learning and 3D Hologram. Both techniques have individually been shown to be effective in teaching technical concepts which require a strong visual competence. Variables specific to the learning environment are identified based on research from multiple areas of learning, including inductive learning, cognitive thinking, constructivism, assistive technology and extrinsic motivation. The research is validated using a control group, which learns by way of educational videos, and a test group, which uses the presented varied learning environment. It is found that the technique learning value and the ability to maintain attention are higher in the test group. The framework presented in this research is widely applicable for Lean training efforts in multiple domains, including manufacturing, supply chain management and healthcare.

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Chapter 1

Introduction

Manufacturing industries are seeking alternative approaches to increase their global competitiveness. One of the major industry practice is "Lean" Manufacturing (LM), as LM concentrates on reducing non-value-added activities with respect to changing business trends. Achieving successful lean implementation requires major planning in inventory management, equipment quality and material sourcing [48]. However, employee training is found to be useful in achieving the above mentioned planning [43]. There are various angles associated with employee training, and the ability to gain insight on a proposed future process remains critical [43]. Regardless of lean efforts taken by the organization, the employee knowledge, if not considered, can significantly reduce the impact of lean implementation.

There are many barriers for an organization's lean transition. Employee training is considered as the most unnoticed barrier [16]. [34] suggest that organizations utilize Co-operative learning (CL) in which employees learn while they perform their day to day jobs/tasks [5]. One of the advantages of using CL is the ability for the employee to learn from the problems faced by the organization in a series of online video modules. The major drawback of the present employee training method is the inability to specifically account for employee engagement [64]. Hence, there is a need for designing a training methodology that focusses simultaneously on employee engagement and employee knowledge gain. Furthermore, designing an adult learning methodology differ from student learning methodology in terms of employee engagement and cognitive skill gain, in which both of the factors are perceptual. Research done by [30] introduces a new training methodology,

Team Based Learning (TBL) is constructed primarily based on employee engagement. TBL creates a learning environment increasing active interaction and participation by forming small groups of learners. Since the introduction of TBL, many educationalists agree there is a significant increase in interaction & participation levels within the learners during the training session [31].

Designing a training methodology requires measurement of knowledge gained through interaction in the classroom, as interaction and employee engagement are directly related [64]. The pyramid hologram (PH) is presented as a study tool to increase team interaction within the learners. This thesis concentrates on utilizing the combined advantage of TBL-PH in teaching LM as there is insufficient research evidence in this particular field. This research is focused on providing an approach for designing and validating an effective training program for LM.

1.1 Background

Over the past few decades, employee training has been considered as one of the vital characteristics to increase the efficiency of a process [5]. Organizations practicing Co-operative learning (CL) to teach employees benefit simultaneously from saving time off work and flexibility of video lectures [34]. Although these benefits are short term, interaction within the employees during a training session is not considered. The primary difference between CL and Team-Based Learning (TBL) is the ability to create an interactive training session. [2] suggest the purpose of a learning is to help interaction and create a sense of involvement within the employees, directly impacting productivity. TBL based training session in adults build strong communication within the small groups, thus interlinking components of employee engagement, learning success rates and the ability for the employee to discuss & provide feedback [57]. Studies done in various industries requiring, interaction of employees to increase productivity, demonstrate TBL as an effective learning method. Steadily, there are many organizations migrating to the TBL as they are long term and has an effect on employee turnover rates. However, it is impractical to create a TBL session without measuring the levels of interaction. Breaking down interaction into, procedural and

conceptual knowledge gain provides researchers to measure interaction levels indirectly [16]. Albeit TBL assist in creating an interactive training session, cognitive learning ability and the motivation levels of the learner are still not measurable. PHH is a study tool that has been scientifically proven to help adults learn by extrinsically increasing participation and interaction levels using assistive technology [21]. Theoretically, combining TBL with PH Hologram (PH) measure all aspects of procedural and conceptual knowledge gain. This multi aspect measurement is employee-centric and values' employee feedback by collecting response sheets by way of conducting survey and questionnaire to continuously improve the training session [12].

Just-in Time (JIT) manufacturing is the Japanese way of production and has seen a linear increase since the last four decades [36]. The primary motivation for this adoption being, prioritizing customer demand before any production profitability [36]. A higher control over the demand, predictive failure and increased quality is achieved through the JIT practice. As the customer demand changes, the organization adapts to lean techniques swiftly. In a standard JIT manufacturing line, various operations take place in a parallel manner. These operations are 80% employee centric and require appropriate resource allocation and critical thinking for increased efficiency [2]. Prior to change, managers undergo a training session specific to a particular lean initiative. Additionally, designing a training session is to have a long-term benefit that can be utilized as demand varies. The ability to trace back employee engagement, amount of knowledge gained, and efficient use of technology remain critical on lean implementation. A training methodology should be able to track these factors and provide feedback to the organization.

1.2 Procedural and Conceptual Knowledge Gain in Lean Training

Designing a training methodology for adults requires decomposition of metrics in a particular subject being trained. As adult learning methodology do not include the learner interaction as vital, about 23% of lean implementation fail [40]. Research evidence on lean training by [4] provide substantial proof for the following:

- Reduce defect rate
- Increase process quality
- Identify system redundancy and anomalies.
- Increasing skill utilization to supply cross-functional workforce.

The above factors are generalization for a successful lean implementation, having interaction as a metric chained within the factors. Measuring interaction levels are observational and cannot have an analytic measurement system [47]. Therefore, breaking interaction into procedural and conceptual measures provide trainers to design analytics supported training methodology. This section provides a brief introduction to the advantages of designing a lean training session incorporating procedural and conceptual knowledge gain. Since lean concepts are a composite of conceptual and procedural techniques, consideration of variables in lean training is essential. Conceptual techniques are philosophical and require an employee to articulate their function and other important functions to complete a job/task. On the other hand, procedural techniques are considered to be direct and require standard instructions from the supervisor and periodic maintenance to maintain the effectiveness of the lean technique. The following are the major effects of incorporating procedural and conceptual knowledge gain in lean training

1. Increased motivation for learning and performing a technique
2. Higher noticeability of a problem

3. Ability to increase cognition with respect to the surrounding
4. Construct solution for undefined business processes
5. Efficient use of technology

These effects can be incurred by designing an appropriate adult learning methodology that enhances effective lean implementation.

1.3 Problem Statement

Based on past research efforts, in lean training, there has not been sufficient evidence to prove the following:

- There is a need to identify an effective lean training methodology
- There is a lack of interpretation of learning variable responsible for an interactive lean training session.
- There is an insufficient representation of metrics to measure learner feedback during lean training
- There is a need to demonstrate the advantage of Team Based Learning - Pyramid Hologram to teach specific LM techniques.

1.4 Approach

Since this research study is focused on providing an active learning environment to managers of the organization, fig 1.1 provides a visual representation of the approach followed in the study. Various phases elaborately explain the study as the following:

- *Phase 1* - The metric identification involves narrowing the variables suitable for designing an interactive training session. This phase involves a two-factor identification model that is built on procedural and conceptual knowledge gain and interconnection within the metrics.

- *Phase 2* - In teaching methodology phase, two major training methodologies with their teaching tools are compared by their ability to directly or indirectly measure the metrics selected from the previous phase. A study tool based on literature, is used to better render the selected training methodology.

- *Phase 3* - The experiment analysis phase examines the hardware, software requirements for scrutinizing the selected teaching methodology and the teaching tool by creating test and control groups. This phase is a prototype of the practical implementation and studies the effects of each teaching methodology from the previous phase.

- *Phase 4* - The data collection phase involves providing survey forms and test questionnaires to collect the analytic outcome of the test and the control group. The questionnaire are supplied to the groups before and after the training session, while the survey is provided to the test group to validate the metrics selected in *Phase 1.*

- *Phase 5* - The analytical phase determine the statistical inference between the control and test group. This phase provides analytic result to approve or disapprove the hypothesis. The analytic measurement obtained in this phase is co-related with the variable identified in the first phase to validate the application of the selected teaching method and study tool from the second phase.

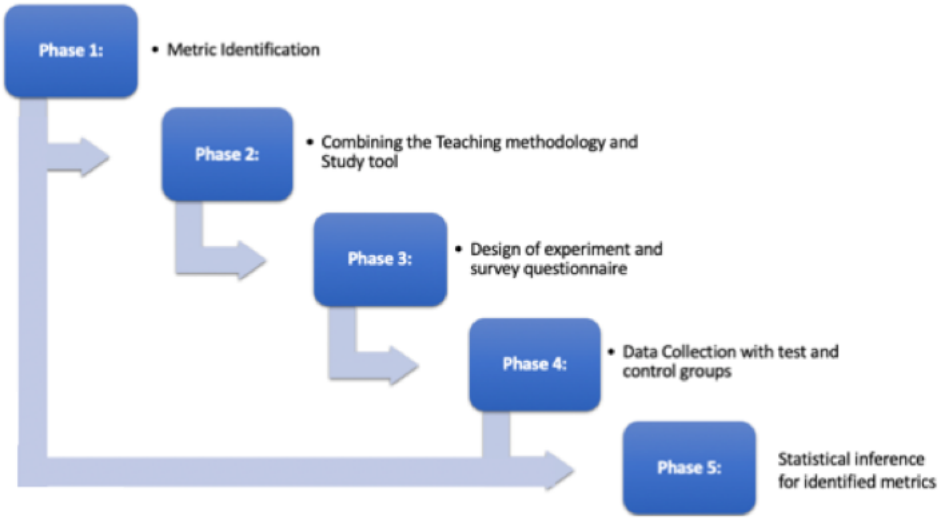


Figure 1.1: Approach of the research

1.5 Scope Of The Study

The varied methodology of learning introduced in this study has the following limitations:

- This study concentrates on the combined effect of TBL - Pyramid Hologram as a study tool and not each individual learning methodology.
- This varied methodology can be used only for learning specific lean techniques.
- This specificity is based on the organization's perspective, as the novelty of using the study tool is limited only for a few training sessions.
- This study does not measure the amount of accountability outcome from the learner.
- Taking the longitude of the study into consideration, only the percentage of improvement in learning and its corresponding co-relation effects are studied with the help of certain variables.

1.6 Thesis Outline

This thesis has been divided into *five* chapters. Fig 1.2 explains the flow of this thesis. As Chapter 1 introduces the ideology of the research study and the effective outcome to the organization in terms of knowledge gain. Chapter 2 explains the various literature review associated with other teaching methodologies and their disadvantages of integrating the other methodologies to learn LM. Chapter 3 introduces to the specific steps carried out in implementing the methodology. Chapter 4 discusses the in-depth procedures of conducting the experiment and validating the effects of the varied learning methodology. Chapter 5 explains the future direction of this methodology and the continuation of this research.



Figure 1.2: Flow of the thesis

Chapter 2

Literature Review

Manufacturing organizations venturing into LM seek ways to reduce waste and increase production by training the workforce. The impression of organization engaging the employees through training has given a new viewpoint in academic research. Traditional methods of teaching are considered less effective for engaging employee in a classroom environment due to the lack of interaction within the learners. This chapter explains specific fundamentals and differences between various teaching methods, teaching tools, adult learning variables and the role of the variable in lean training. The following sources were utilized solely for this literature section while keeping the keywords in mind, they are:

- Academic books from The University of Tennessee
- E-books from the the Knoxville Public Library
- Google articles published by various academic journals
- Google search results on conference proceedings
- Onesearch peer reviewed articles provided by The University of Tennessee.

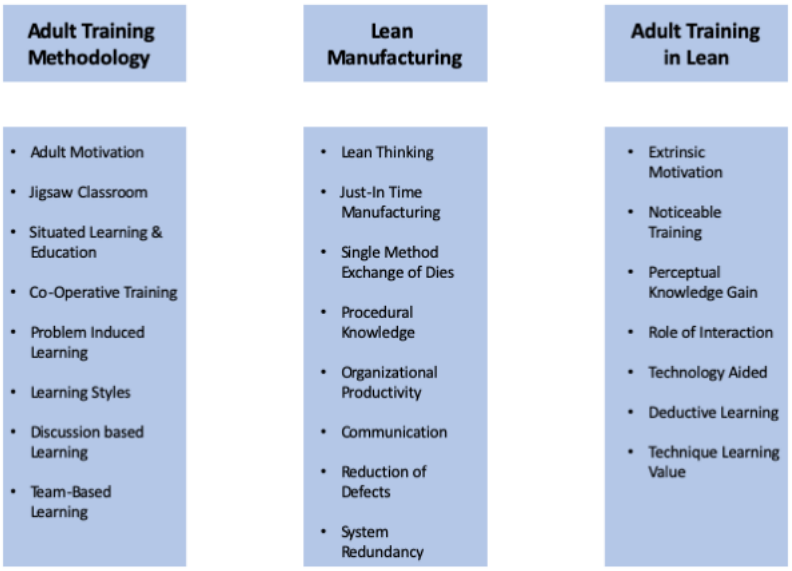


Figure 2.1: Keywords for the literature search

The holistic idea of the literature review is to understand the basics of adult training for employee engagement and increasing effectiveness in lean implementation. The literature review for this research has been conducted by identifying the keywords on adult training, lean manufcturing and role of interaction in classroom. Based on the keywords from fig 2.1, an elaborate list of parameters were created for further scruteny. Thus identified parameters required specific domain analysis, which was accomplished by valuing the individual impact of the identified keywords which is represented in fig 2.2.

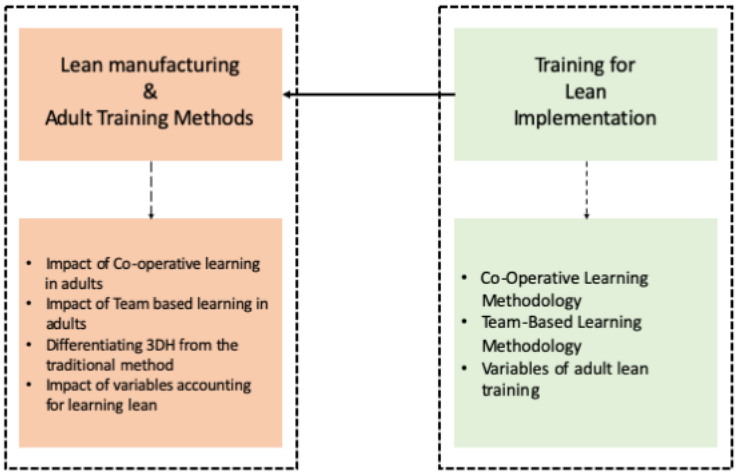


Figure 2.2: Domain analysis of literature review

2.1 Co-operative Learning

Co-operative learning for employees have been used by organizations to account for the time saved by the organization in training the employee. [34] explains the practical ease of implementing co-operative learning by using video modules. These video modules provide support to the learner in having a remote training session. In this type of remote session, the learner does not get the opportunity to interact with fellow learners. This lack of opportunity results in poor cognitive skill gain. Research work done by [25] and [1] is represented in fig 2.3 help summarize the following about co-operative learning

1. Identifying specific problems faced by the employee that require training.

Table 2.1: Impact of Co-operative learning in adults

Author	Title	Summary
[34]	Evaluating the quality of learning in computer supported co-operative learning	Provides evidence of using co-operative having better learning outcomes Presents the need for group based learning Discusses the importance of interaction within learners

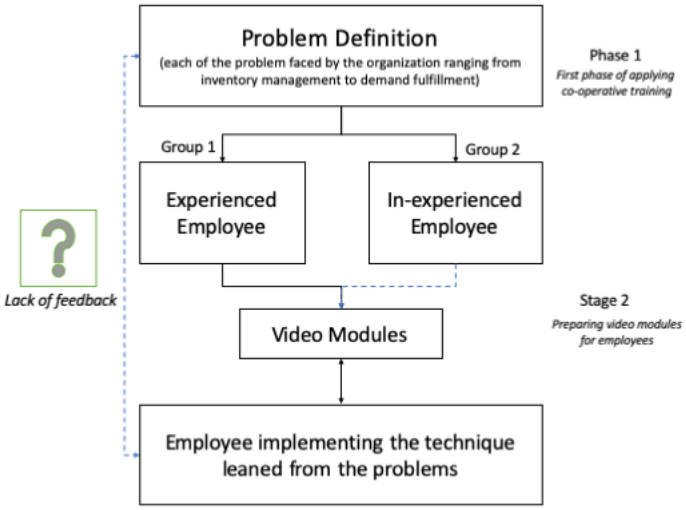


Figure 2.3: Co-operative learning in practice

2. Segregating the employees into experienced and inexpereicned
3. Providing the experienced employee with different training modules
4. Allocating video modules with problems faced by the organization to the less expereinced employee
5. Disrupting the knowledge gain by improper maintenance of training reports.

2.2 Team - Based Learning

Table 2.2: Impact of TBL in adults

Author	Title	Summary
[57]	Social and cognitive factors driving teamwork in collaborative learning environments: Team learning beliefs and behaviors	Establishment of group based learning in classroom Proof of performance increase in group learning Examines the importance of interaction within the learners

Team based learning is the method of inducing interaction within the learners to enhance the knowledge gained in a particular training session. In this method of training, the perceptual skill gain takes place in an involuntary format. [7] explains the intricasies of using team based learningin educating nurse practioners in a hospital. Creating an interactive classroom environment provides the scope for learning through communication within the learners. Some of the standard definitions are represented in fig 2.4 for team based learning are:

- Ability to provide an objective to an individual group for learning.
- Employee solidarity increases while learning in groups and reflect directly in the performance.
- Motivation from external sources form the roots of team based learning as the groups outside the classroom environment continuously improve their knowledge gain.
- Active feedback within the learners help assess each individual in a self perceptual format
- Reflection of the amount of skill gain is immediete in team based learning because it is centered around interaction and active discussion.
- The advantage of less functional instructor can be utilized as the teams are progressing towards a self sufficient method og cognitive learning value.
- The ability to transform an employee into a multi functional employee is paced at higher levels due to the provision of group activity.

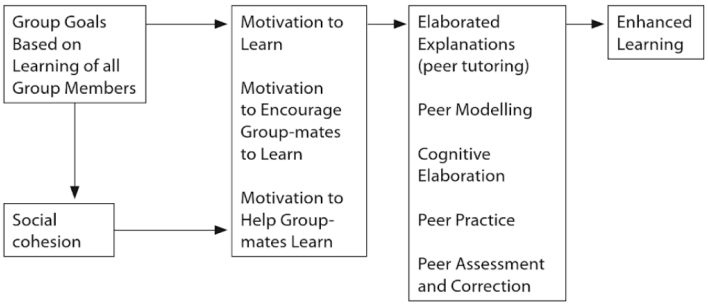


Figure 2.4: Team based learning program

[19] has provided academic evidence for using team based learning in educating medical professionals for effective performance. In the research article, the author has established the connection between the following:

- Relationship between interaction within learners and the effect of procedural and conceptual knowledge gain.
- The importance of identifying the efffect of procedural and conceptual knowledge gain in various educational domains.
- The significance and lack of recognition of metrics associated with measuring the learning effectiveness due to interaction.

Though the above statements are a summary of the research article, work done by [15] signify the importance of a study tool to facilitate the implementation of team based learning. According to [11] an ideal study tool should include consideration of the following factors:

- Motivate learners to speak at a louder tone within the classroom environment rather than observing the training session.
- Provide room for moving within the group to stimulate interaction within the group members.
- Impart the idea of providing feedback to the group members, therby receiving feedback in an involuntary approach.
- Increase relationship between the learners of the group for better interference and to avoid miscommunication.

2.3 Pyramid Hologran - Study Tool

The pyramid hologram (PH) is considered as a superior study tool in education. One of the major applications of PH is the ability to prototype a model instantly and the portability of the structure.

Table 2.3: Impact of Pyramid Hologram in classroom

Author	Title	Summary
[3]	A review of application of 3D hologram in education: A meta-analysis	Initiation of 3D Hologram as visualization tool for learning Provides space for interaction within groups Increases involvement of learner inside the classroom

This is very different from the " Pepper Ghost" (PG) type of Hologram as there is less space required to demonstate the PH, the PG holograms are considered for entertainment purposes, while the PH is considered to the study tool in this research. This is due to the ability of the PH to concentrate small groups of learners around the device during training session. Work done by [24] help articulate the application of PH in training program which requires interaction within the learners as represented in the table 2.3. Visualization of the technique being a vital component of PH, work done by [3] help understand the use of PH in the following educational domains

Table 2.4: Use of Pyramid Hologram in various educational domains according to [3]

Author	Title	Field	Utility
[49]	Use of 3D hologram technology in engineering education	Engineering Education	Increase perceptual knowledge gain
[18]	A real-space interactive holographic display based on a large-aperture HOE	Photo-Optical Instrumentation	Easier recognition of ambient colors
[9]	Holographic projection technology: the world is changing	Business Education	Better understanding of customer requirements
[42]	Evaluation of brain models to control a robotic origami arm using holographic neural networks	Neuroscience	Identification of fast paced moving objects
[61]	Holograms as teaching agents	General Medicine	Increase patient satisfaction and gain better operation insights
[33]	Holographic interface for three-dimensional visualization of MRI on HoloLens: A prototype platform for MRI guided neurosurgeries	Pharmacology	Comprehend the co-relation between the various drugs and its effect oh human body

2.4 Adult Learning Variables

In academia, research studies suggest the inclusion of variables for measuring an adults' perceptual aspects in learning [4]. This perceptual measurement is a key factor as this provides sufficient evidence regarding the effectiveness of the training program. [37] also suggest that the training program for the employees in an organization has a direct impact on the emploees' performance. Research done by [43] and [16] in lean training suggest considering the following in a step by step manner, which has been represented in fig 2.5

1. Adult learning variables
2. Variable that account for interaction in a classroom
3. Metrics specific to each of the variables

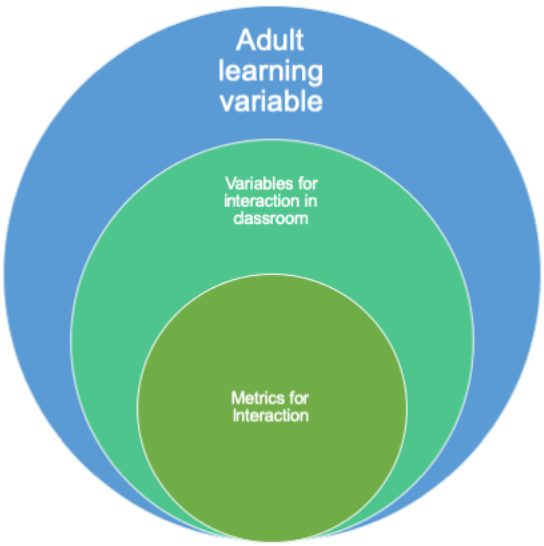


Figure 2.5: Adult learning variables considering interaction and classroom

2.4.1 Extrinsic Motivation

The idea to learn or invest time on something due to external factors that is fascinating is known as extrinsic motivation [26]. Research done by [10] and [13] helps us understand the role of using external factors to teach as the perceived level of compatibility. Discussing extrinsic motivation levels and their use in learning among manger training is essential as it has a higher impact. In learning, behavioral intention is mostly required to maintain the retention levels of the study, external factors has a positive effect on influencing the attitude required for learning. One of the main reasons is the perceived effect of learning is better. Since this form of training sessions are learner focused, it helps in a positive effect on the learner environment [66]. In adult learning, there are specific metrics that help researchers mesasure the effectiveness of a specific variable. Since extrinsic motivation is a resulting effect of external factors, each of the external factor cannot be used as a metric due to logical reasons [10]. Hence, the following metrics listed are the best combination of adult learning, external motivation and lean training

1. *Environment:* The surrounding elements of a training session considering faculty, collegues and teaching method is referred as environment [26].

2. *Competence:* The ability of the learner to assess themselves on a single factor is consideres as competence in learning theories [66].

3. *Active Feedback:* Research studies suggest, the ability for the learner to recieve immediate response from the faculty as active feedback [13].

2.4.2 Inductive Methodology

The method of teaching principles and techniques in a better qualitative manner is inductive way of teaching. Deep research done by [39] and [38] helps us understand the importance of inductive methodology and active learning. Engineering education requires the study material to be rendered in a very specific and concentrated way. This specific rendering is the inductive methodology that helps establish a visual relation between the specific theories learnt and their practical application within the same training session. When organizations

implement a lean methodology, the facility is more likely to receive a major change and initially employees getting used to the new way of working takes some time. But the managers that design the process require knowledge about the organization's vision. The inductive way of active learning is the best alternative that provides varied dimension of an environment during learning [32]. The parameters involved in measuring the inductive method of a training program are the following

1. *Personalization:* The training content being specifically focussed for each individual while studying each individuals' learning perspective is personalization [38].

2. *Achievement of Goal:* The provision of noticability of specific problem in a relatively smaller domain is know as acheivement of goal in a training session [32].

2.4.3 Cognitive Support

The ability of a study tool to help learner solve practical problems using critical problem-solving capabilities within the learner mind provides certain degree of cognitive support. One of the main advantages of using active learning to teach LM techniques is that, during implementation of the technique the learner should be able to exercise the novelty of the technique in all appropriate places [67]. This novelty in implementation is done by a learner when the subject gets refined in their mental model [29]. The ability of active learning session to constantly maintain the quality of output creates the learner to stay attentive. This cognitive element in active learning forms a psychological way of retaining information that are critical for decision making. Adult learning mechanism have the following parameters to measure the cognitive skill gain of the learner

1. *Abstraction:* Assesing the potential of a learner to disect various parts of the training session and combine the disected parts to form a single solution is abstraction [29].

2. *Technique Learning Value:* Measuring the potential of a learner to self-identify and report specific findings from the training session [67].

3. *Latching:*The ability of the learner to device a cause specific solution from a metaphysical problem or a technique being trained is latching [67].

2.4.4 Constructivism

Active learning enhances the learner capacity to develop the concept of constructive learning. As the visual tool helps the learner to create an abstract yet relatable theory in their own mind helps to retain information precisely [29]. Thus, stored information in the memory is due to the active engagement of learner during the training session. This form of learning helps the learner to improve their personal learning outcome that has a high positive effect on the learner during implementation of the technique. In constructivist mechanism, literature suggest the following parameters

1. *Maintain Attention:* In adult learning mechanism, the attention span of a learner is about 9 minutes [17]. Prolonging this attention span to help the learner build concrete strategies from the training session is known as the ability to maintain attention of the learner [29].

2. *Evaluate New Theory:* From the learner perspective, assesing ones own ability to construct advanced solutions from the training session is the ability to evaluate new theory [60].

2.4.5 Assistive Technology

Reading maps from a two-dimensional view to a three-dimensional layout with the help of electronic device is a fine example to explain the use of assistive technology in reading. The application of an active classroom can be of great significance for the learner to get the hollistic view of the study material. Though internet modulesare a way of learning, a training methodology that enables assistive technology is most certainly required for learner to experience the formative way of learning [22]. Parametrs associated with the assistive technology in adult learning mechanism are as follows

1. *Performance:* The ability of the technology to perform the basic requirement of a training session [22].

2. *Self-Efficacy:* The self-measure of a learner to asses the reliance of the assitive technology and account the benefits of using the technology for future use [6].

3. *Availability:* This is simply the availability of the asssitive technology to provide the resources required for the learner in a training session [35].

4. *Ease of Control:* The ability of the assistive technology to facilitate the learner during the training session in terms of carrying the device, reachability and affordability of the device [44].

2.5 Literature Review Criterion

Most industry experts challenge the idea of providing training to employees to implement the lean initiative. Adequate proof and various factors that help to measure the effectiveness of a learning environment is required. This section reduces the complexity of this convolution concept; while explaining & comparing the factors with previous publications by distinguishing research articles based on the following conditions

1. Analyzing the importance of interaction and discussion in a training session.

2. Role of Team Based Learning in learning LM concepts.

3. Importance of having a study tool for a learning concept.

4. Effect of Extrinsic Motivation in Adult learner.

5. Effect of Inductive Methodology for a learning environment.

6. Role of Cognitive Support for critical thinking.

7. Constructivism in adult learning and implementing LM.

8. Function of assistive technology in learning outcome.

Each of the factors have been identified from the literature and a table has been created. For each factor that contains Y, N, P (Y=Yes, N-No, P=Partial) the following content of tables explain each article with information in relation to other factors. Ideally proof for a learning methodology that explains sustaining a solution must have all the *eight* columns should have a Y. This denotes the use of integrating learning method, study tool, and various

psychological factors [35]. Implementing learning activities for employees in workspace environments has been less explored and the reason found in the literature is provided in the table 2.5. Most of the publications in this domain have identified the potential use of various learning techniques that might serve a purpose to sustain a solution, there has been no distinct study that explains the reason for choosing a specific learning methodology for case specific industries.

2.6 Research Gap

A diverse literature review with respect to training methods for adults have been considered and presented in the best possible manner. The various adult learning variables and their corresponding metrics have also been examined. Exploring more into the literature review, a major shortcomming of adult training methodology and lean manufacturing principles in academia research has been noted. Although, there has been barely any research done to examine the effect of interaction within learners and a fitting training methodology to track the outcome of the adult training method. Furthermore, there is no evidence of a comparison study done between various adult training methods considering interaction within the learner as a vital factor, which is demonstrated in this research study.

Table 2.5: Summary of the factors considered for the literature review

S.No	Publication	f1	f2	f3	f4	f5	f6	f7	f8
1	[28]	Y	N	P	Y	N	N	N	N
2	[20]	Y	N	Y	P	N	Y	N	Y
3	[62]	Y	P	N	P	P	N	Y	P
4	[45]	Y	N	P	N	N	Y	Y	N
5	[58]	N	Y	N	P	Y	N	Y	P
6	[31]	N	Y	N	N	N	N	P	Y
7	[59]	P	Y	N	Y	N	P	Y	N
8	[7]	N	Y	P	P	Y	N	Y	P
9	[21]	N	N	Y	P	N	N	N	N
10	[55]	N	P	Y	N	N	N	N	Y
11	[52]	N	P	Y	P	P	N	P	Y
12	[26]	N	N	P	Y	N	P	N	P
13	[10]	N	P	P	Y	Y	Y	Y	Y
14	[8]	N	N	P	Y	N	N	Y	P
15	[50]	P	N	N	Y	N	P	N	N
16	[23]	N	P	P	Y	P	Y	Y	N
17	[39]	P	N	N	P	Y	N	P	Y
18	[38]	N	N	P	P	Y	Y	P	N
19	[17]	P	N	N	P	Y	N	Y	Y
20	[67]	N	N	N	P	N	Y	N	N
21	[29]	P	N	P	N	N	Y	N	P
22	[37]	N	N	N	P	P	P	Y	P
23	[51]	P	N	P	N	P	N	Y	N
24	[14]	N	P	N	N	Y	N	N	Y
25	[46]	P	N	Y	P	N	P	N	Y
26	[44]	N	P	N	Y	N	Y	P	Y

Chapter 3

Methodology

This chapter provides a structured approach to bridge the differences between the previous academia studies done in this domain and the research objective. The following details are discussed in this chapter:

- Comparing different training programs to analyze their effectiveness.
- Study the effect of interaction within learner for lean training.
- Measure the variables co-relating interaction and learning in a classroom environment.

3.1 Research Framework

Varied learning environment is the combination of Team - Based Learning (TBL) and Pyramid Hologram (3DH) in a formal classroom environment. TBL is the approach of forming small groups of teams ranging between 2-4 learners inside the classroom. PH is the holographic representation of a video-based lecture. The objective of this research is to provide substantiate evidence for using the varied learning environment (VLE) in lean training sessions. This chapter illustrates the approach designing, implementing and validating the VLE based on the research gap. Focus has been concentrated on the following factors as a guide to follow the research methodology:

- Selection of variables associated with employee engagement

- Combining TBL - PH together for experimentation
- The hardware and software requirements for the Pyramid Hologram
- Design of the questionnaire based to help in comparing between the learning techniques
- Analyzing the quantitative metrics to determine the success rate of VLE

Traditionally organizations follow a training methodology that is based on short video modules, this is referred as Co-operative Learning (CL). Throughout this research study, CL has been used for comparison with the VLE & benchmarking purposes. The fundamental difference between the traditional training methodology and the proposed design of VLE have been represented in fig 3.1, which are :

- Identifying the importance of interaction within the learners for effective skill gain
- Measuring the variables responsible for interaction after the training session

The proposed training program that has been represented in figure 3.1 explains the inclusion of variable before the training program and measuring the effectiveness of the variables after the training program. This inclusion of variables before & after the training is done to gain analytic insight on the effect of interaction within the learners. The identification phase of the methodology represented in fig 3.2 explains the selection of variables and the corresponding metrics required for an interactive training session. The second phase explains experimentation of VLE and comparing VLE to the existing teaching method. The analytical phase explains the various statistics tools used to validate the results from the experimentation phase and provide evidence of co-relation between results and the variables identified in the first phase. The analytical phase has equal impact on the study as it supports the approach for designing a VLE for lean training.

The contribution from this research study is the observation of increased cognitive skill gain within the learner. This observation has been self-reported by the learners as cognition is a perceptual factor. The reason cognition being a perceptual factor and the observation noted from this study is vital, because the learning outcome and cognitive skill gain are directly related in measuring the effectiveness of a training program.

3.2 Identification Phase

Organizations utilizing training to develop their workforce need proper understanding about the interconnection between various factors. The association of variables with respect to the learning outcomes, the selection of study tool are the factors interconnected. This phase discusses the systematic approach of identifying the theoretical background of VLE. First, the characteristic requirement of lean training is matched with other learning variables. These variables are then subjected to a two-factor validation model for determination of adult learning metrics. Adult learning metrics are measurable factors that represent an adults' learning outcome. These adult learning metrics are set as standards for determining a lean training methodology. Thus, selected teaching methodology is profoundly related to the lean training requirements.

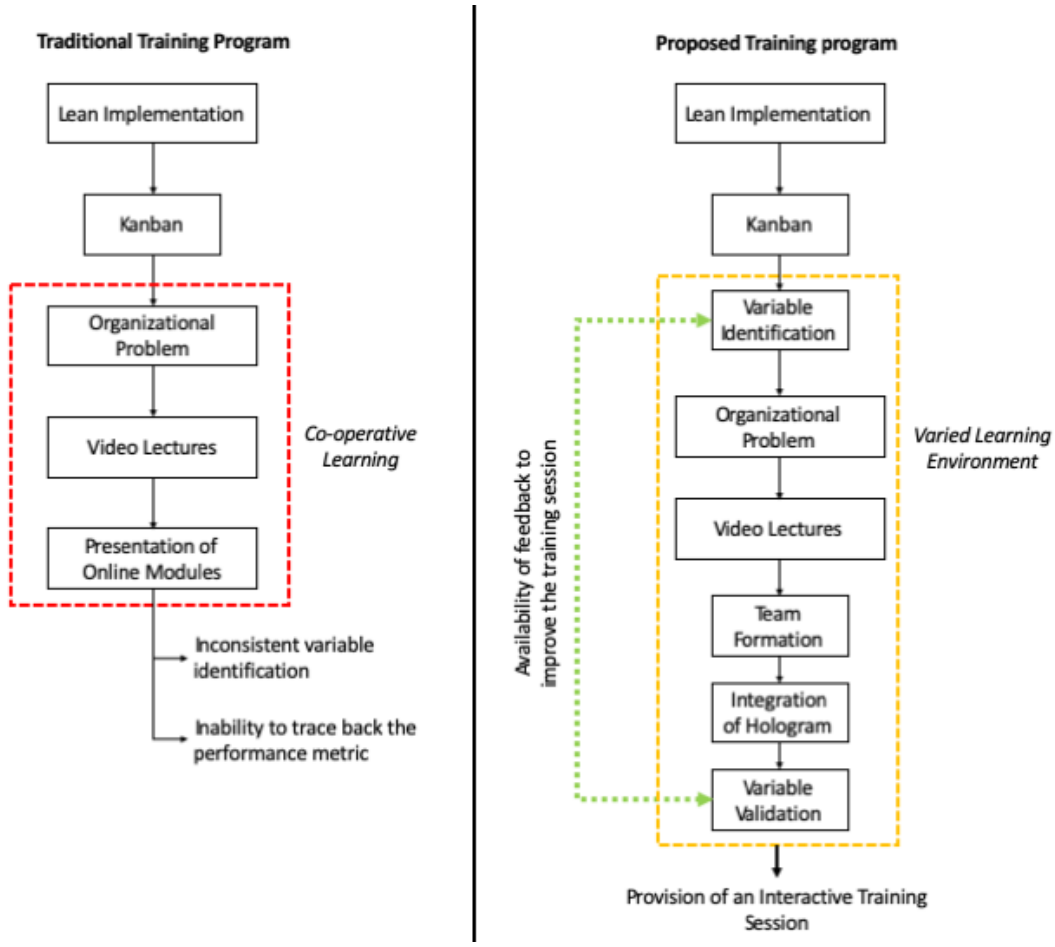


Figure 3.1: Difference between the tradition and Proposed training program

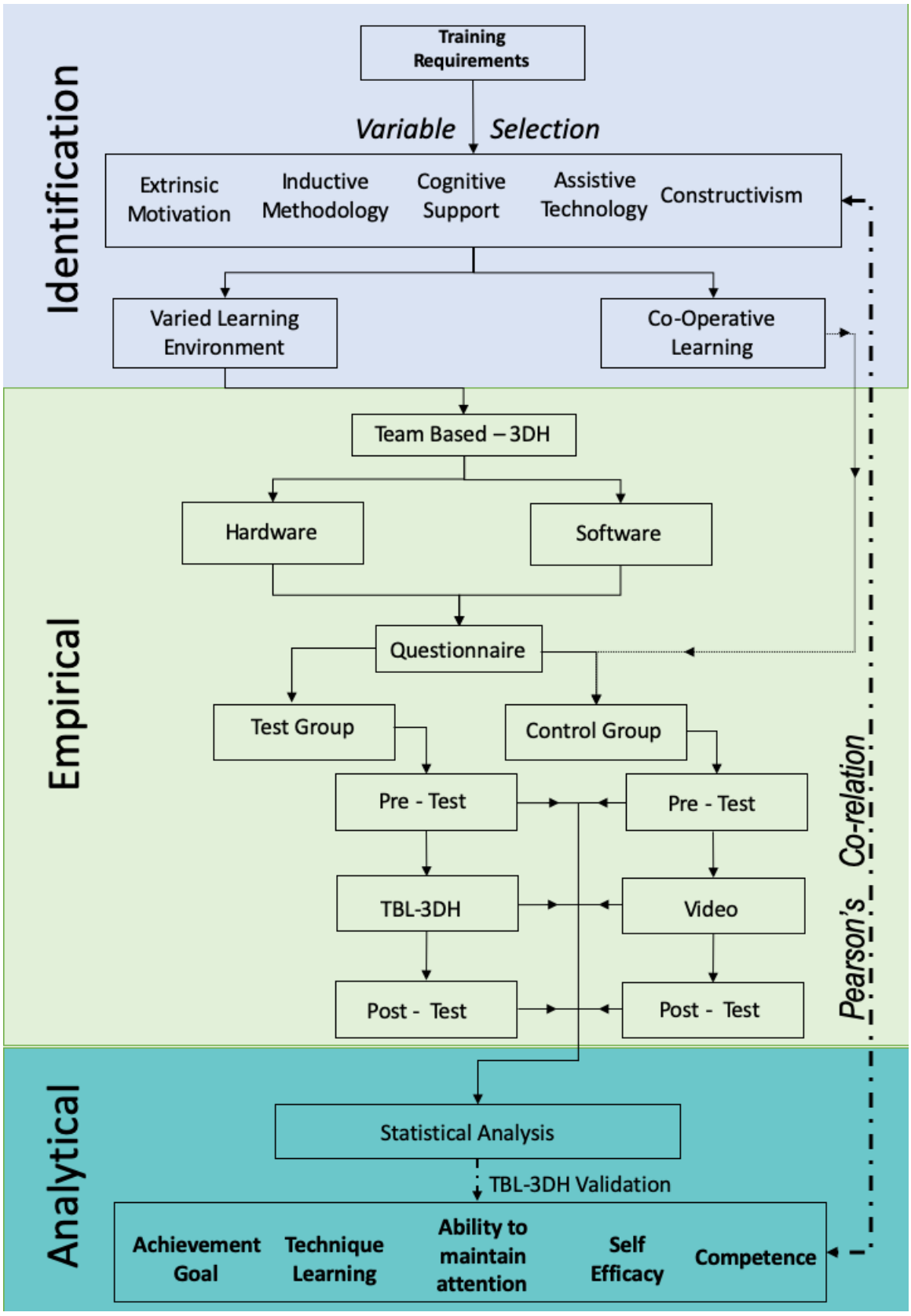


Figure 3.2: Research Framework of this study

3.2.1 Variables for the Varied Learning

Designing a teaching methodology for lean requires appropriate examination of variables that help in accounting for adult learning outcomes. This section discusses the process involved in variable selection required for teaching procedural & conceptual techniques. The variables identified are then scrutinized further for deciding the measurable adult learning metrics. Utilizing a two-factor validation model can help in the selection process. This validation results in determining a single adult learning metric from each Learning-Variable. The process involved in selecting a metric is dependent with respect to other four variables, reduce the complexity of the measuring process and based on the level of shared compatibility. As shown in Fig 3.3, this is based on the literature found on designing a learning mechanism for adults in various domains and learning methodologies.

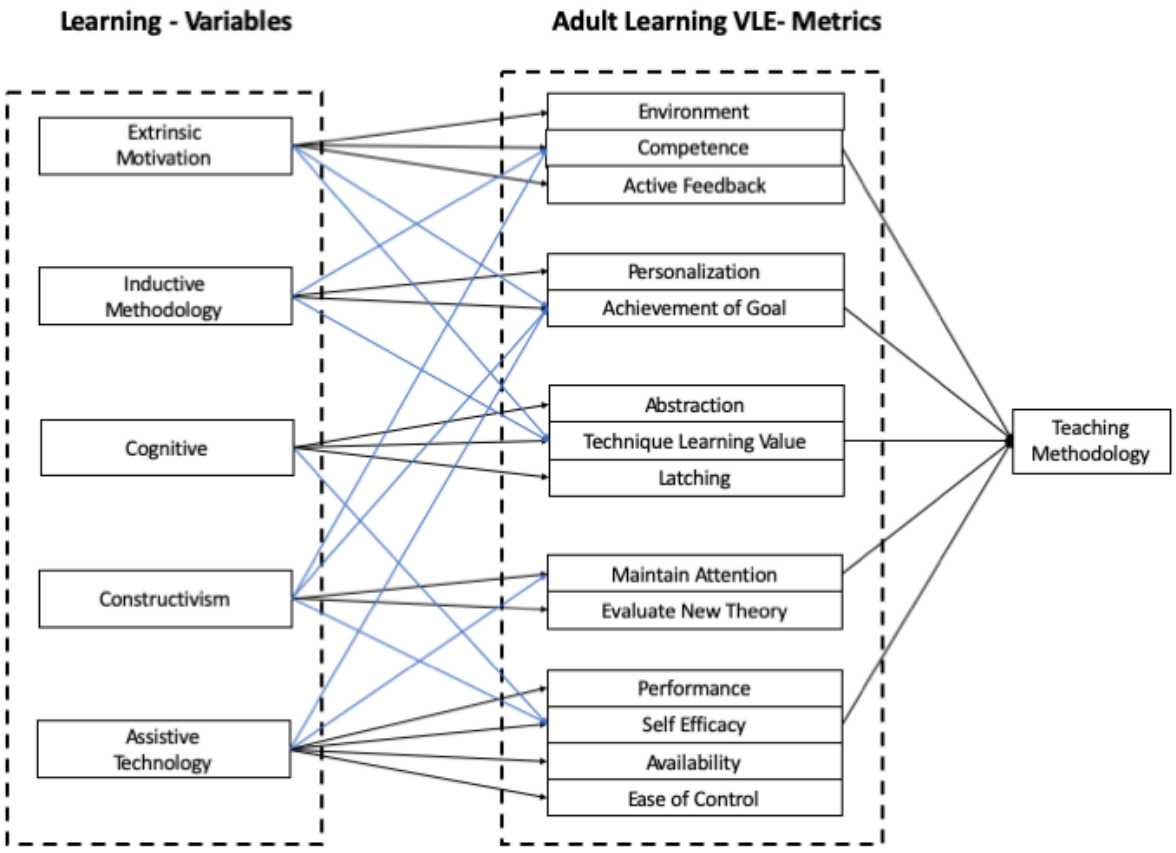


Figure 3.3: Variable Selection

- *Competence:* Lean activities involves repetitive actions, these actions require extrinsic motivation for the learner to learn the repetitive action, hence competence is direct related. Inductive methodology and competence are associated by the two-factor validation as research suggests gaining confidence through competence helps in increasing adult learning outcome. Association of constructivism with competence is through the ability to gain knowledge in the absence of a formal classroom environment.

- *Achievement of Goal:* In lean manufacturing, activities are repeated and a specific pattern is always followed towards the output of the activity. This output embedded training process that requires to gain insight on a technique and its intricacies are directly related to inductive learning methodology. Extrinsic motivation is considered to be closely associated with determination of goal as adults tend to compare their results with their peers, this forms as a secondary level of motivation for adults to increase their learning effectiveness. Constructivism helps in validating goal achievement as a metric due to the ability of adults to gain knowledge from external sources and set personal targets. Assistive technology helps in achievement goal as the learner is able to visualize the larger perspective of their role in inductive learning environment.

- *Technique Learning Value:* Lean training requires effective repetition of the learnt technique, measuring the perceptual technique learning value is required should be done to assess the training methodology. In formal classroom environment, inductive methodology and extrinsic motivation have been traditionally supporting the use of technology for adult learning methodologies. This step interconnects the perceptual cognitive knowledge gain with lean training by measuring the technique learning value.

- *Maintain Attention:* the ability to maintain the learner attention throughout the training session to study the effects of the training session helps analyze the learner perception. This measure of the span is directly related to the constructive knowledge gained, as this represents the learner ability to make critical decisions. in regards to the two factor validation, *Assistive Technology* helps in validating the attention span

Competence = f (Extrinsic Motivation, Inductive Methodology, Constructivism)

Achievement Goal = f (Extrinsic Motivation, Inductive Methodology, Assistive Technology, Constructivism)

Technique Learning Value = f (Extrinsic Motivation, Inductive Methodology, Cognitive)

Attention Span = f (Assistive Technology, Constructivism)

Self Efficacy = f (Cognitive, Assistive Technology, Constructivism)

Figure 3.4: Functions of the two-factor identification

as the absence of a tutor proves to be beneficial and the learner has no control over the technology.

- *Self-Efficacy:* Perceptual studies are self-oriented and the use of technology to assess the measure is directly interconnected to designing the adult learning methodology. Constructivism actively co-relates with self-efficacy as the learner identifies their ability to establish a relationship with the learning methodology and their learning outcome [67]. Cognitive ability of the learner supports self-efficacy as a metric to measure the technology from the learner's perspective. This is supported by conducting interview, surveys and performing face to face discussions.

The resulting function of each metric has been summarized in fig 3.4. The next subsection provides a comparative explanation between the largely followed adult learning methodology in organizations and the proposed Team based Learning-Pyramid Hologram, while considering the lean teaching requirement and the selected variables.

3.2.2 Co-Operative Learning

Co-operative Learning (CL) is the most accepted format of teaching lean in organizations [54]. CL consists of less time-consuming modules while not compromising on an employee's regular job tasks. Training lean concepts through this method has been proven to have benefits. This form of learning concentrates on individuals that have a prior manufacturing background. From the perspective of the organization, implementing this form of training is considered to be cost efficient as the employee is actively working while learning the technique

in parallel. Video Based Learning (VBL) and Problem Based Learning (PBL) are common methodologies that provide an effective environment for Co-Operative training method. One of the major down slides of using VBL and PBL are the selection of inappropriate study tool. In VBL, there is lack of teaching method while the study tool is the video output. This two-dimensional video output has a greater positive impact as it encourages in remote study of the learner but lacks active participation. The teaching method of PBL is utilizing the ability of the learner to learn a technical concept based on the problem faced by the organization.

The study method of co-operative training is case specific, but there is competence deficiency from a learner perspective. One of the ways to provide insight to lack of competence is the employee's inability to visualize information on the broader picture of the lean technique utilized. This provides as a source for lack of information exchange. During lean implementation this lack of information forces employees to revert back to the existing process. However, tracing back the constructive knowledge gain, there are evidence with respect to learning from video modules.

3.2.3 Team Based Learning

Teacher - Guided learning by integrating active participation and discussion in a formal classroom has been proved effective for adult education. The application of TBL can be differentiated from various formats such as VBL, formal in-class and face-to-face learning. This differentiation is due to the active interaction phenomenon. During training sessions, procedural and conceptual knowledge gain requires adequate levels of interaction within learners. Team based group of students actively interact during the training session. This interaction component is useful in gaining conceptual knowledge as the group of learners discuss the holistic approach of a particular technique actively during the training session, while the effectiveness of procedural knowledge gain has not been verified in previous research articles. Hence the application of video modules is necessary to test and evaluate the effect of procedural knowledge gain during the implementation of team-based learning.

This study method encourages learners to actively participate in the training session. The ability of the learner to articulate and decide the goal of the training session is induced

in this teaching methodology. Forcing the learner to discuss in a classroom environment increases the learning potential by proportionally increasing the attention span of the learner [31]. Learning LM requires this extended span of attention for better knowledge gain. The shortcoming identified in this teaching methodology is the lack of a study tool that forces learner to interact within the group.

3.3 Empirical Phase

This section gives a stage wise explanation of compiling the aspects of TBL and PH together to form the varied learning environment (VLE). Designing the experiment to analyze the effects of the VLE by utilizing test and control groups. Information based on the team formation, selecting a lean technique, PH hardware & software requirements, designing the questionnaire will be discussed in a step-by step procedure for industry experts to implement the VLE. One of the key factors to understand the authenticity of VLE is validation. Since, the hypothesis of VLE is active interaction in classroom has a positive impact of adult learning outcomes, a validation method that does not encourage active interaction is required. The industry standards of training is using *two dimensional educational* video, which also serves the purpose of validating this research method. Furthermore, this section of the methodology explains the demographics of the test and control groups in details with the assumptions related to each set of respondents.

3.3.1 TBL-PH

Team Formation

The objective of this section is to explain the necessary factors required to form a team. Studies previously done shows that social intelligence plays an active role in learning among adults. Forming known groups of learners can benefit the development of constructive knowledge. Formation of teams within the learners can take place in two ways based on [57], they are:

- The extent of the lean initiative taken by the organization determines the size of the group.
- Cause specific employees responsible for particular lean activities have to be grouped in a single team.
- If the organization requires all the manager level executives to undergo training, then learners of four can be grouped together.
- Considering the technological advantage of PH, teams can be comprised of 4 learners as the maximum limit and 2 learners as the minimum limit.

Pyramid Hologram - Study Tool

Based on co-operative training, it is evident that the use of video-based modules is imperative. A video-based tool that can be utilized in implementing TBL is the pyramid shaped Hologram.

The reason for the use of Pyramid Hologram technology in the VLE is that it encourages the learner to engage in active interaction with their peers during the training session while reducing the complexity of the learners cognitive visualization. The lean techniques that can be used in VLE based on the literature [36]as shown in table 3.1

Table 3.1: Potential lean techniques that can be utilized from using Pyramid Hologram

S.No	Lean Technique	Advantage	Hologram's utility
1	Kanban Production	Schedule and minimize work in progress	Helps visualize the workstation and identify signal cards
2	Poka - Yoke for mistake proofing	Mitigate mistakes and defects	Aids in discussion of possible areas of the facility to mitigate defects
3	5S - Sort, Set in order, Shine, Standardize and Sustain	Standardize and increase efficiency in workplace	Visual edge to force areas of improvement and maintain standard.
4	Heijunka for Level Scheduling	Identify batch size based on demand	Visualize the capacity of the workstation
5	Just - In Time manufacturing (JIT)	Manufacturing based on pull process	Support in reducing space by visualizing and discussing countermeasures
6	Overall Equipment Effectiveness (OEE)	Measure productivity based on availability, performance, quality	Helps to visualize and engage in discussion regarding waste and redundancy in a process
7	Total Productive Maintenance (TPM)	Assess the maximum operational time of an equipment	Benefit the learner by assisting in forecasting the mean time to failure of the equipment

3.3.2 Pyramid Hologram - Hardware Requirements

The approach for constructing a PH prototype consumes very less effort. The PH used in the VLE has to be portable, easy to use and cost efficient. These reasons help the study tool to be utilized in any formal classroom environment. This can be made possible with the help of a pyramid shaped hologram made from acrylic plastic sheets that are transparent, portable, sturdy and also economically less expensive [27]. The next step of a hardware requirement is the output screen where the video can be viewed. This Hologram project two dimensional images/videos as a 3D image/video when the pyramid shaped acrylic structure is placed on top an output screen. The output screen can be a LCD/LED television, foldable laptops, tablets, or even mobile phones as shown in fig 3.5. The acrylic structure is constructed based on the dimensions of the output screen. One of the sample calculations for constructing the structure is as follows:

- Step 1: Considering a 15.6-inch tablet for designing a PH tool and half a meter square shaped acrylic sheet.
- Step 2: Determine the display size of the output device without considering the bezel.
- Step 3: After determining the screen size to be 15.11 X 10.18, cut a hollow pyramid shape in a trapezoid format off the acrylic sheet.
- Step 4: The dimensions of the acrylic sheet are upper length is 1.18 inches, lower length is 7.08 inches and the height are 4.13 inches, repeat this procedure *four* times for the four sides of the pyramid.
- Step 5: The angle between each side should be 70 degrees, this specification helps the reflection of the video on each side converge together and form a single reflection on the center of the hollow pyramid.
- Step 6: The above measurements can be scaled up or down depending upon the screen size of the output device.

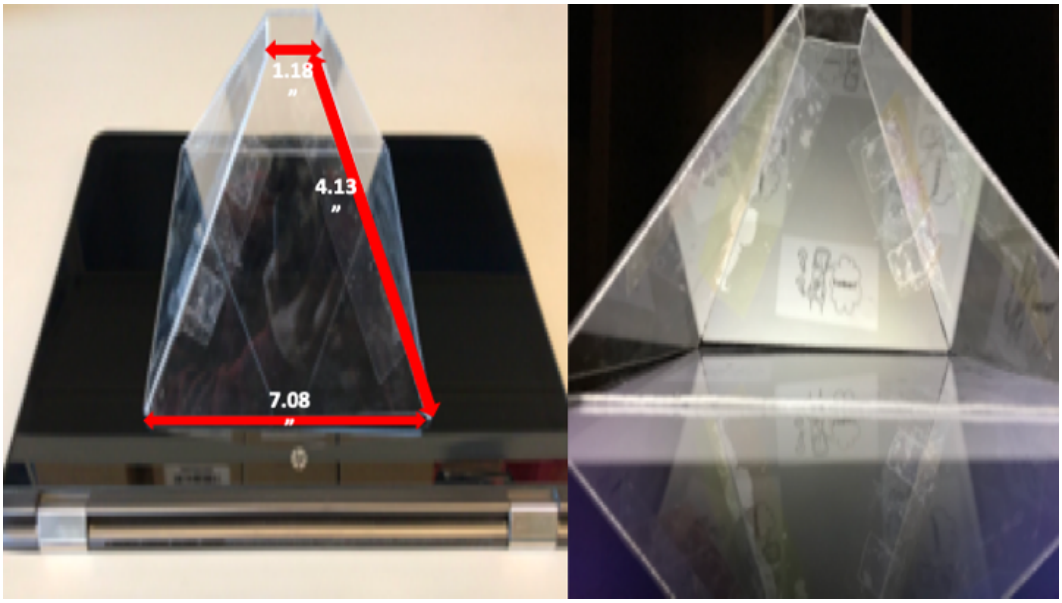


Figure 3.5: Hardware for the technology

3.3.3 Pyramid Hologram - Software Requirements

This sections explains the step by step procedure of converting a two dimensional video into a compatible video for this varied learning environment. This conversion can be done in Microsoft PowerPoint as shown in fig 3.6 with the help of a lecture note or a previously created two dimensional video with respect to the technique.

- Step 1: In Microsoft PowerPoint, make sure the slide size is within the aspect ratio of 16:9,
- Step 2: Insert a letter X connecting all the four sides of the slide.
- Step 3: Place a two-dimensional video in the slide screen space, adjusting the length and breadth of the video to accommodate 3 other videos intersecting on the four sides of the X alphabet.
- Step 4: Duplicate the video *four* times while rotating the video counter clockwise by 90-degree every time, placing them each on one side of the X alphabet.
- Step 5: Animate the video such that all the video start *with previous*.

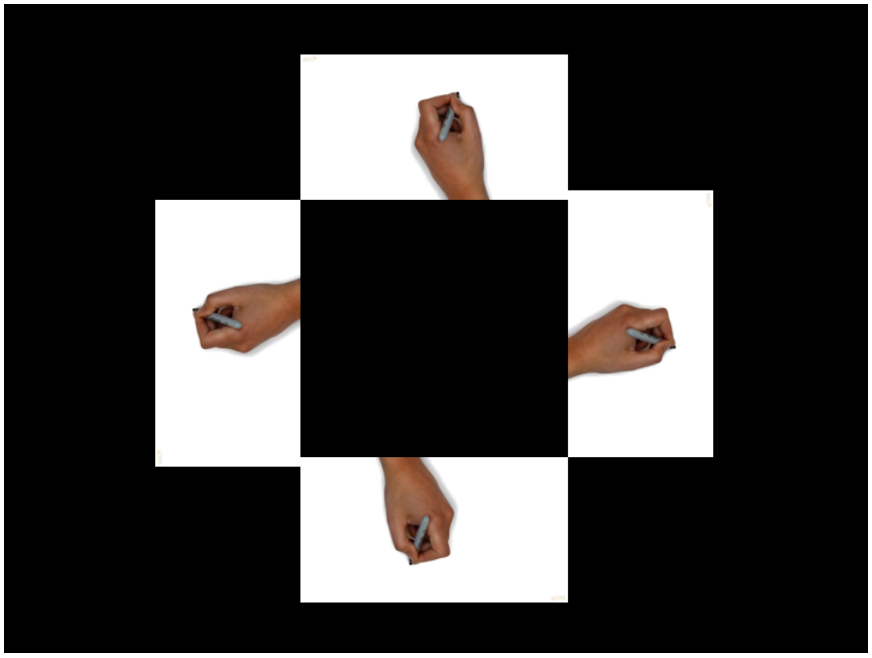


Figure 3.6: Video formation for the varied learning environment

- Step 6: Format the background to enhance the video with gradient colors.

3.3.4 Designing The Questionnaire

The VLE proposed in this research study has to be tested with a quick response feedback method. Considering the time as a valuable unit for testing the methodology, a questionnaire relating to a specific topic is prepared [68]. This questionnaire acts as a tool to measure the learning outcome of the VLE. Examining deep into this dynamic of preparing a questionnaire for this research, the following steps are :

- Step 1: Selection of a technique relevant to the lean initiative done by the organization.
- Step 2: Maintaining the complexity of the questionnaire such that the hollistic approach of a particular lean technique can be learnt.
- Step 3: Designing the level of competence for each question based on the demographics, for this research the demographic audience are adults with intermediate or novice level of lean knowledge.

- Step 4: Giving little room for pictures or diagrams, this helps to analyze whether the varied learning environment induces critical thinking within the learner's cognition.
- Step 5: Providing each question with multiple choices of answers, this step of the process increases the ease of the learner to answer the question.
- Step 6: Check for redundancy or repetitive questions with less practical application.

3.3.5 Test Group

This group of respondents form the core research audience as the results of the research are directly applicable for this demographic of respondents. The assumptions that may be made for this group of respondents are:

- Engineering graduates undergone formal instruction in lean.
- Practicing lean in an active industrial setting.

3.3.6 Pre-test Questionnaire

The respondents are handed out a set of questions prepared by following the instructions in section 3.3.4. The next step of the process is that the respondents get a small brief regarding the research and the role that they play by responding to the questionnaire. For privacy reasons, the respondents are not supposed to mention their names anywhere inside the response sheets. Following this step, the respondents individually choose the best option for all the questions subjected to the lean technique. This individuality is vital for assessing the amount of knowledge gain by each respondent.

3.3.7 Hologram Session

In this phase, the respondents are asked to view Pyramid Hologram video compatible with any electronic device that has the contents that is required to answer the technical questions relating to the lean technique. The duration of the video depends on the content covered in the lecture, which also included a solved example. During this process, the respondents

that are in teams actively engage in discussion with fellow teammates such that the team members engaged in becoming partners to construct shared knowledge.

3.3.8 Post-test Questionnaire

The last phase for the group is to fill in the post test questions which is the same as the pre-test questions. But the responses made here assist in analyzing the learning outcome of the respondent on a particular lean technique and effect of technology in assisting to gain lean knowledge.

3.3.9 Control Group

In this research study, the control group of learners are students currently pursuing their graduate degrees. This is done so that the test group are already exposed to the formal way of teaching including *slide show presentation*- lecture type and *two dimensional video* lectures. The assumptions made while selecting learners for this type of group are:

- Respondents are enrolled in an active graduate program.
- Respondents have prior lean knowledge, which asserts they have attended at least one lean class during their course.

The control group follows the same procedure as that of the test group, while having a few limitations, they are:

- Anytime during answering the responses or viewing the educational video, a team or a group is not formed.
- The educational video is viewed in a two dimensional format.
- The respondents do not answer the survey for variable analysis, as the variables associated in the survey fits only to the VLE.

3.4 Analytical Phase

This phase explains the details for analyzing the projected results of the empirical phase. One of the key elements of this phase is validating the research study while bridging the research gap. The comparison between the Co-operative Learning group and Team Based Learning group is interaction centered. Therefore, there is a requirement for the TBL group to undergo further testing. This test excluding the control group is to ensure learners provide substantiate evidence to prove the research objective.

3.4.1 Data Analysis For The Questionnaire

Behavioral research studies include human subject participants. Validating human subject results has few barriers. One of the barriers is variation in responses. The degree of variation can be analyzed by performing statistical analysis. T-test is a statistical tool that can be utilized to measure the variation between the test and control group data. Performing t-test between the pre and post questionnaire data will be helpful to analyze variation found in the learner responses.

Since there are two groups focused in the research study while each group answering two types of questionnaire, a validation tool is required. Two-way Anova with repeated measure is carried out so that each group of learners are tested based on the measure of learning outcome. The comparison between the final test score is the learning outcome in test and control group. This two-way Anova with repeat measure is conducted in the following procedure:

- Visualize the data outcomes of the pre and post test scores in the form of histogram. This form of visualization help determine the data points that are out of the Gaussian curve. These data points that do not fall under the curve can be grouped together for residual calculation.

- Verify the normality test for residuals. This normality test is done to determine the goodness of fit. This goodness of fit is a vital metric for data obtained from human subjects.

- Analyze the mean between the groups to examine the central tendency of pre and post test questionnaire. Calculate the variance to analyze the deviation of recorded data from the central tendency. The next step is to calculate the p-value of each group individually. This p-value provides significant statistical evidence based on confidence interval. The p-value to be used in this test is equal to 0.95. Based on the p-value, the null hypothesis or the alternate hypothesis can be accepted. In this research study, p value <0.05 provides substantial evidence to prove test group has better learning outcome when compared to the control group.

Validation Survey

After completion of the questionnaire, the respondents in teams are individualized to answer a 19-question survey. This survey is instrumentalist with a 5 point Likert scale that includes questions relating to the variables selected for validating the VLE. The survey is answered individually by the respondent while considering each question from a team-based perspective. This is helpful for the respondent to analyze the dynamics of their team and the amount of shared knowledge.

3.4.2 Descriptive Analysis

The variable associated with the survey represent each factor associated with different branches of learning, a regression model has to be created by following steps:

- Check for co-relation of various factors identified as variable. This is done to provide proof of relationship between the variables identified for teaching lean and VLE.
- Identify the highest co-relating factor within the five adult learning metrics. This step is vital to provide a hierarchy of metrics suitable for the cause specific learning technique.
- Check for various multi variate tests to analyze the effect of variation between the metrics. This step enables the teaching methodology designer to assess the vital and trivial metrics required for teaching lean techniques.

- Examine Pearson-Correlation with single tail to conclude the major effect of the VLE. The effect of the adult learning metrics and the VLE can be mathematically represented using the relationship between the metric that pertains the highest rank in Pearson-Correlation test with its corresponding elimination level.

- The summation of each metric identified in the variable selection phase and their corresponding Pearson-correlation score provides the linear regression graph.

The advantage of using a linear regression model is to assess which metric pertains to the advantage of the learner. The metric with the lowest score implies that re-iteration or redesign in the learning material is required. Regression provides the trainer the ability to decide & forecast the effect of VLE. Conducting regression positively impacts the sustainability of the teaching methodology while concentrating on the aspect of active interaction and discussion.

Chapter 4

Data Collection and Results

The various outcomes of the proposed methodology and explanation from the outcomes are explained in this chapter. The final results of all statistical analysis are derived using the SPSS software provided by The University of Tennessee. The basic empirical requirements are satisfied before conducting the experiments. The next sections explain the practical bifurcation between control and test group. Finally, the statistical interference and analytical data are presented to provide sufficient evidence to validate the VLE. Nonparametric Statistical analysis is followed throughout this chapter as it involves the use of descriptive statistics, visual representation and prior statistical inferences.

4.1 Mutual Empirical Requirements

The data collection and validation of the proposed research methodology is carried through performing test questionnaires and survey forms. Since the research finding directly impacts the employee, virtual use of equipment cannot be implemented. Before the data collection can be initiated, there are several requirements to be satisfied which are represented in fig 4.1

- The video of the lecture content for the control & the test group.
- Pre & Post test questionnaire for comparison between both the groups.

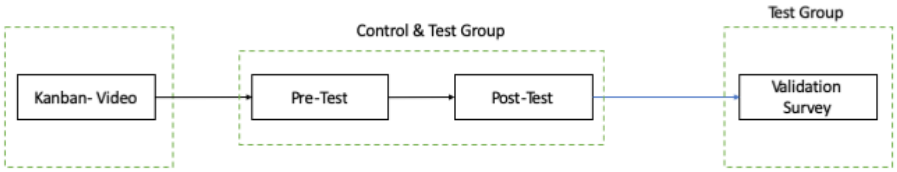


Figure 4.1: Flow of data collection

4.1.1 Preparation of Video Lecture

The control group and the test group view the same video lecture based on Kanban - a workflow management technique. The difference between the two groups being, the test group experiences the same video in a PH output device. According to [53] designing a Kanban video for an adult training session should consider *three* learner-oriented aspects, which are

- Work Visualization

  This encompasses the systematic assistance and the success factor achieved by the technique. The ability to visualize the workflow and categorize into started, soon to be completed and completed has to be present in the training module. This is represented in fig 4.2

- Work-In Progress Control

  The training module should provide an approach to maintain the work in progress, as

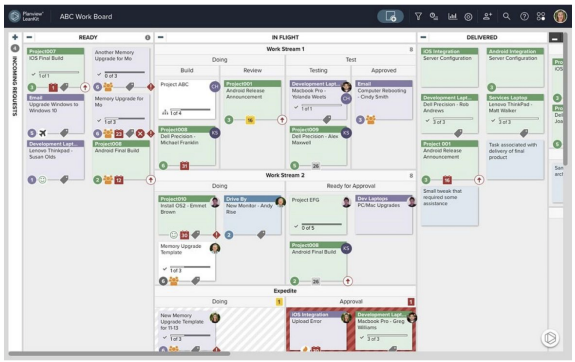


Figure 4.2: Classifications & Work Visualization

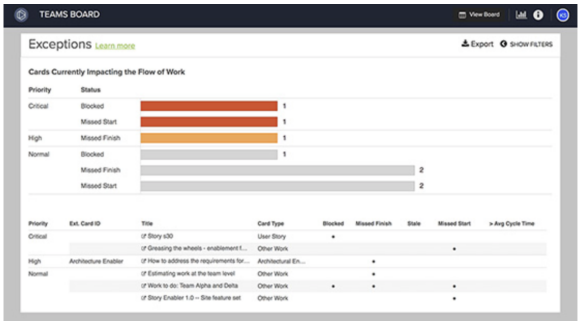


Figure 4.3: Management of Flow with respect to the Demand

over-production leads to waste. Provision of this content in training modules is directly related to cognitive domains of knowledge gain.

- Flow Management

  Delivery of products to match the customer requirements require optimal management of product flow. This being the pivot concept of Kanban, requires to be present in the training module as represented in fig 4.3

Based on the above requirements, a lecture video was prepared. The video length was 12 minutes with two major bifurcations. The first 25% of the video consisted of standard Kanban definitions and the industry standards. The other 75% of the video consisted of a case study as an example to help the learners visualize and have a complete understanding. The pizza example case study was conducted by abiding all the three aspects mentioned above and has been represented in fig 4.4

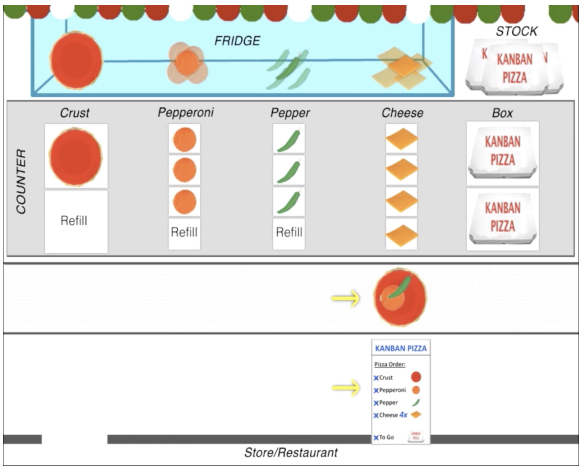


Figure 4.4: Case study example with customer demand

4.1.2 Pre & Post Test Questionnaire

Measuring the effectiveness of a training program has been evaluated by the use of test questionnaires. Since this research methodology introduces a new learning environment, a comparison with existing standard training methodology is required. A standard comparison between the traditional training methodology and the proposed training methodology can be completed by the following steps

- Initially testing the learner knowledge in a particular domain of knowledge.
- Providing a descriptive training session complying standard requirements.
- Finally testing the learner knowledge in the same domain of knowledge.

Similar to other research studies conducted by [63], [65] and [16], this VLE proposition study has also used a single test questionnaire to measure the learner knowledge before and after the respective training session of the control & test group. According to [41] the following factors have been considered during the design and pretesting of the questionnaire

- Repetitive questions
- Paradoxical terms in the questions
- Probability of missing questions from the training module
- Positive estimation of pictures/image representation
- Questions biased on the target(test) group
- Complexity level of the questionnaire

Based on the above listed requirements, a survey with *ten questions* were drafted and sent to The University of Tennessee - Institutional Review Board (UTK-IRB) for human subject regulation purpose. These ten questions were provided with the choice of multiple answers to reduce the ambiguity of the learners to answer each question. This is represented in figures 4.5 and 4.6

Code: _____

Please choose the best option:

1. What is Kanban?
   a. Visual Management Method.
   b. Virtual Management Method.
   c. Verbal Management Method.
   d. Sequential Management Method.

2. Kanban helps in_____?
   a. Reduce Lead Time
   b. Reduce Throughput
   c. Increase Efficiency
   d. Improve effectiveness

3. How does implementing Kanban help in?
   a. Improve predictability and quality.
   b. Increase reliability.
   c. Improve visual ability.
   d. Increase throughput.

4. Kanban translates to?
   a. Sign board/Bill board
   b. Notice board
   c. Black board
   d. Green board

5. How many basic columns are found in the Kanban board?
   a. 3
   b. 5
   c. 2
   d. 8

6. In a single card Kanban System, when will the single card be taken?
   a. Once the minimum stock quantity has been reached.
   b. Wait till the end of the day.

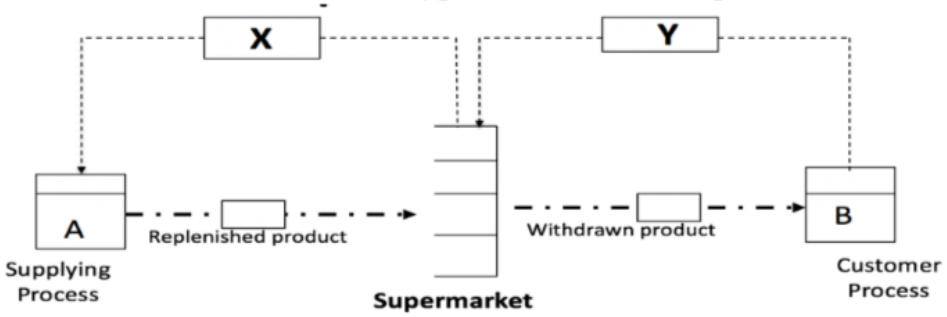
Figure 4.5: Pre & Post Test Questionnaire Page 1

c. Penultimate card has to be reached.
d. Second batch has been reached.

7. A standard full container has the _____ color?

a. Green
b. Red
c. Blue
d. Yellow

8. In this picture below in Place of X, what type of Kanban takes place?



a. Production
b. Withdrawal
c. Materials
d. Batched Kanban.

9. What type of Inventory does Kanban use?
a. FIFO
b. LIFO
c. Shortest processing Time
d. Longest Processing Time

10. What is Takt Time?
a. Total work hours / Customer Demand
b. Customer Demand / Total work hours
c. Material Available / Customer Demand
d. Processing Time * Customer Demand.

Figure 4.6: Pre & Post Test Questionnaire page 2

4.2 Control Group

In this research study, the control group undergoes the traditional training program. Co-operative learning will be the subject used to test the control group. In statistical terms, the control group is the non-treatment group and hence the completion of this group help stabilize the experiment. This section will discuss about the demographics of the group, approach followed in providing the questionnaire and the statistical inferences. The control group of learners were selected form The University of Tennessee. Quick accessibility is the reason for this selection. The background requirements of the group are as follows

- Respondents are aged above 23 years of age.
- Respondents that have been exposed to lean manufacturing terms or have attended a single course of lean management.
- Respondents that have an undergraduate degree in engineering and have been accepted into a graduate level program.
- Respondents were given a brief regarding the research.
- Respondents were provided with a formal consent letter issued by the UTK-IRB
- To maintain the anonymity, the respondents were not asked to provide their name, email adress and contact numbers.
- The respondents have access to internet connection and have a consent to spend 20-25 minutes to participate in the research study

Following the completion of the above steps, the respondents were provided with the Pre-Test Questionnaire as shown in figures 4.5 and 4.6 to get an understanding of their level of knowledge in the Kanban lean technique. The average duration for completion of this questionnaire is about 8 minutes 36 seconds. On the second screen of the research study, the control group were provided with a link to the video prepared by satisfying the conditions mentioned in the section 4.1.1. The duration of the video was 6 minutes and 34 seconds. The respondents were asked to watch the full video to equip their knowledge for further

testing. The third page of the research study for the control group displayed the Post-test Questionnaire as shown in figures 4.5 and 4.6. This is done to maintain the simplicity of the training session and reduce complexity for further analysis. The results of the test are tabulated in table 4.1

Table 4.1: Summarized Results of Pre & Post Test Questionnaire of the Control group

Control Group Assessment results			
Respondents	**Before Assesment**	**After Assesment**	**Group**
Respondent 1	6	5	C
Respondent 2	5	8	C
Respondent 3	7	9	C
Respondent 4	6	6	C
Respondent 5	5	6	C
Respondent 6	5	6	C
Respondent 7	7	9	C
Respondent 8	6	6	C
Respondent 9	7	5	C
Respondent 10	7	6	C
Respondent 11	6	8	C
Respondent 12	7	9	C
Respondent 13	7	5	C
Respondent 14	5	5	C
Respondent 15	6	5	C
Respondent 16	7	5	C
Respondent 17	5	9	C
Respondent 18	6	5	C
Respondent 19	7	7	C
Respondent 20	7	7	C
Respondent 21	7	8	C
Respondent 22	7	5	C

Table 4.1 continued from previous page

Control Group Assesment Results			
Respondents	**Before Assesment**	**After Assesment**	**Group**
Respondent 23	5	7	C
Respondent 24	7	7	C
Respondent 25	6	8	C

The pictorial inferences from the table are represented in figures 4.7 and 4.8

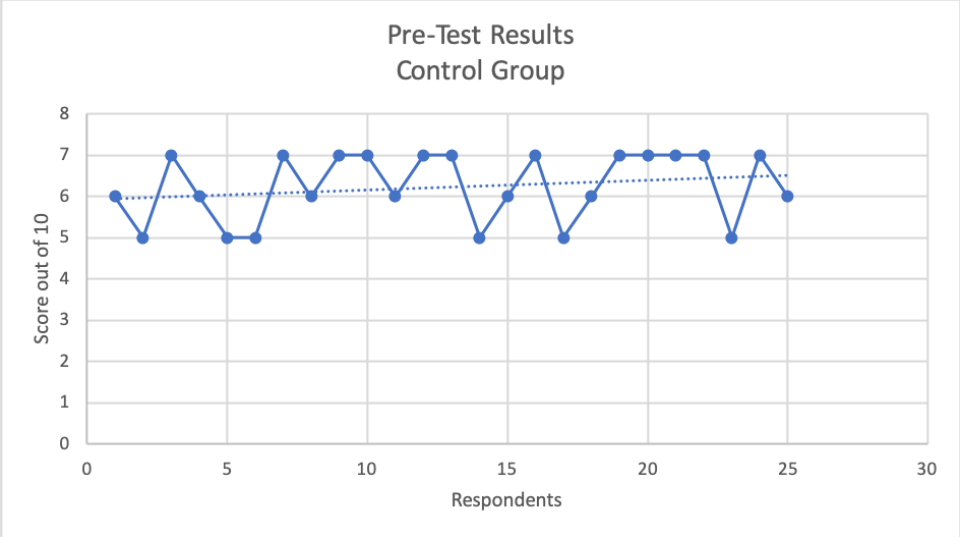


Figure 4.7: Pre Test Questionnaire Line Graph - Control Group

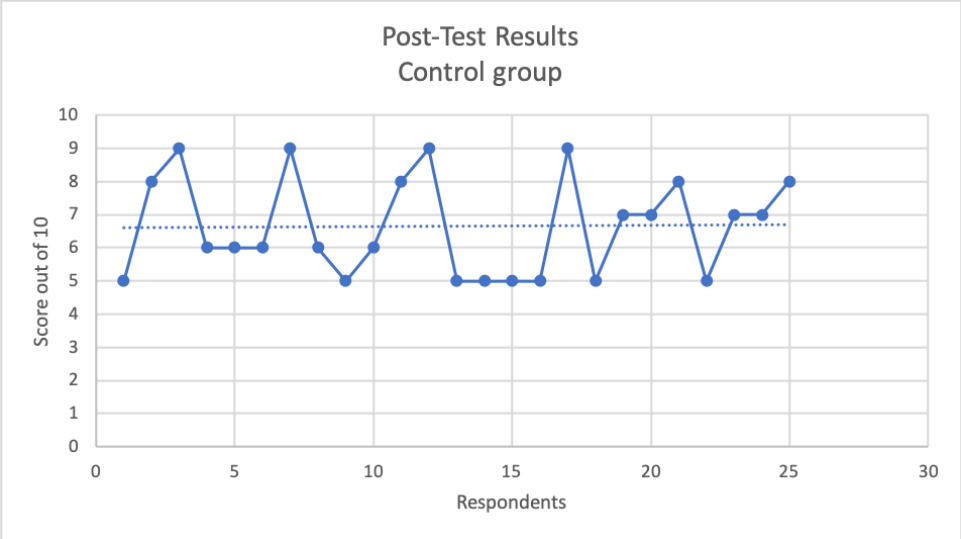


Figure 4.8: Post Test Questionnaire Line Graph - Control graph

4.2.1 Observations and Inferences

The activity review of the control group will be discussed in this section. The observations made by the researchers are based on the line graphs represented in figures 4.7, 4.8 and 4.9 and table 4.2. Initially the results between the Pre & Post questionnaire are dissimilar. There is a slight increase in the average score, but the mode of the results displays the most repetitive score of the learner group. This is critical from an inference point of view as a majority of the learner have a drop-in score. Lack of group interaction, motivation to learn, inconsistency in noticing an issue are the reasons for this drop in the majority of the population [56]. Statistically the collected data is normal based on the Shapiro-Wilk test for normality as represented in fig 4.10.

Table 4.2: Inferences of the Control Group

Control Group Inferences		
Parameters	**Before Assesment**	**After Assesment**
Mean	6.24	6.64
Median	6	6
Mode	7	5

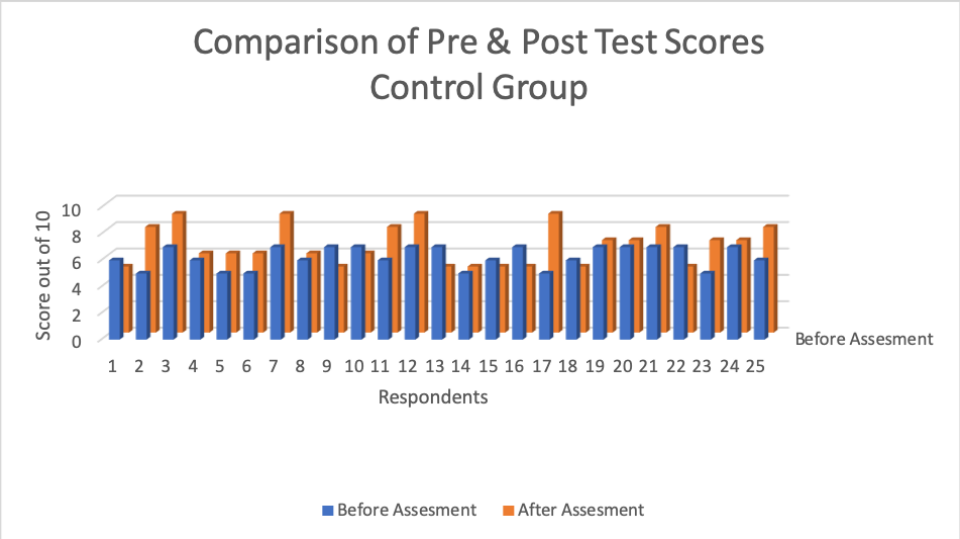


Figure 4.9: Comparison of Pre & Post Result - Control Group Bar Graph

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Before	.300	25	.000	.763	25	.000
After	.186	25	.026	.861	25	.003

a. Lilliefors Significance Correction

Figure 4.10: Shapiro-Wilk Test for Normality - Control Group

4.3 Test Group

The treatment group in this research study involves exposure of the group to the varied learning environment (TBL-PH). Since the standardization of the questionnaire is already established, the approach followed by the control group will be similar to the approach of the test group, the difference being the following

- Initiation of small groups within the learners.
- Provision of PH inside the classroom by following the requirements listed in sections 3.3.2 and 3.3.3.

Since this study involves adults attending a cohort program together, cohesiveness has to be minimized. Solely by providing discussion time before forming teams within the

respondents, each of the respondent receives an opportunity to discuss regarding their individual skills and interests. This is done considering the duration of the research study. The test group population for this research study was 25 (N=25) and the respondents were asked to form teams based on each of their compatibility. After being formed into groups, the respondents were provided with the Pre-Test Questionnaire as shown in figures 4.5 and 4.6 for initial assessment of their current level of knowledge in Kanban systems. Immediately after completion of the Pre-Test Questionnaire, each group of respondents were exposed to the VLE. Once each team has completed the training module, the Post-Test Questionnaire was provided similar to the control group. The final results of the test group are tabulated in table 4.3

Table 4.3: Summarized Results of Pre & Post Test Questionnaire of the Test group

Test Group Assesment Results			
Respondents	**Before Assesment**	**After Assesment**	**Group**
Respondent 1	3	7	T
Respondent 2	2	9	T
Respondent 3	4	9	T
Respondent 4	3	4	T
Respondent 5	3	9	T
Respondent 6	4	8	T
Respondent 7	3	6	T
Respondent 8	3	8	T
Respondent 9	3	7	T
Respondent 10	2	6	T
Respondent 11	3	6	T
Respondent 12	4	8	T
Respondent 13	3	9	T
Respondent 14	3	9	T
Respondent 15	6	8	T
Respondent 16	4	8	T

Table 4.3 continued from previous page

Test Group Assesment Results			
Respondents	**Before Assesment**	**After Assesment**	**Group**
Respondent 17	2	6	T
Respondent 18	4	8	T
Respondent 19	4	7	T
Respondent 20	2	9	T
Respondent 21	3	7	T
Respondent 22	4	4	T
Respondent 23	4	8	T
Respondent 24	2	9	T
Respondent 25	4	7	T

This phase of the experiment provides mobility for the learner to move and communicate with other team members while actively watching the PH video from any of the four sides of the output screen. A clear representation of the scores obtained by the test group are shown in figures

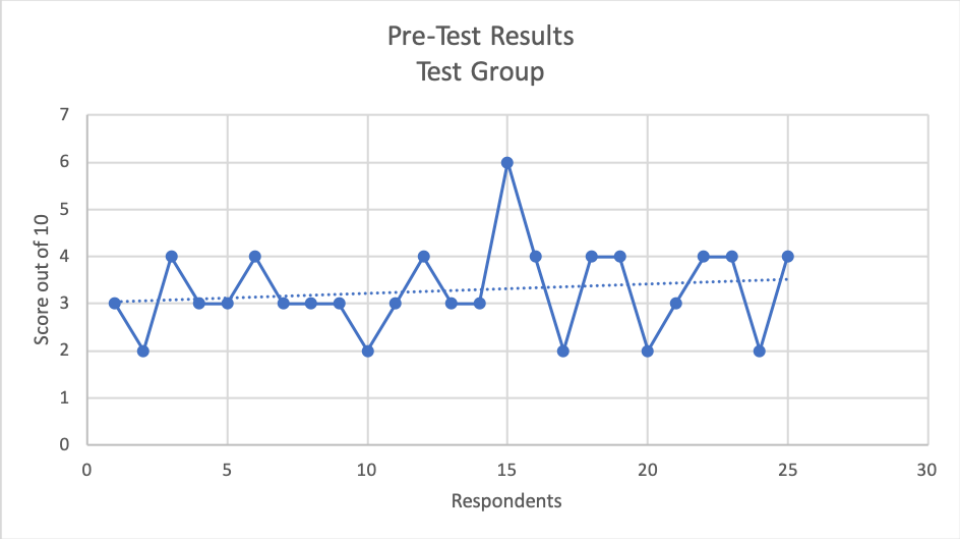


Figure 4.11: Pre Test Questionnaire Line Graph - Test Group

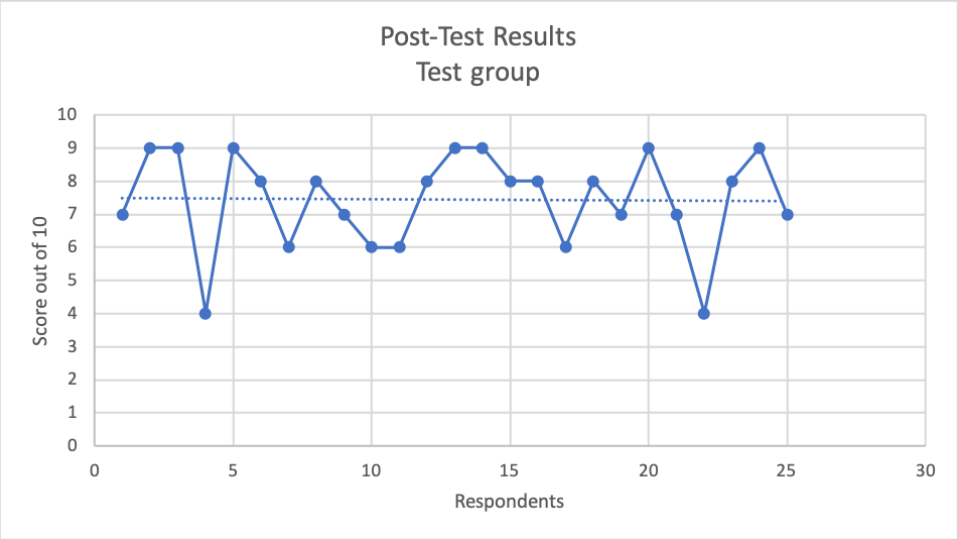


Figure 4.12: Pre Test Questionnaire Line Graph - Test Group

4.3.1 Observation and Inferences

The pivotal group of this research study being the test group, the various factors influencing the result will be discussed in this section. The inferences made in this section are based on figures 4.11, 4.12 and 4.13 and initial statistical derivatives tabulated in table 4.4. A pattern of improvement has been clearly identified from the line graphs of the test group. This proves a major spike in increase of knowledge has taken place between the Pre & Post group questionnaire. This claim is statistically significant according to the p value obtained from the Shapiro-Wilk test where the significance columns are less than 0.05. Based on the literature and the proposed methodology, it is evident that interaction within learners during a training session is beneficial in adult lean training session.

Table 4.4: Inferences of the Test group

Test Group Inferences		
Parameters	**Before Assesment**	**After Assesment**
Mean	3.25	7.458333333
Median	3	8
Mode	3	9

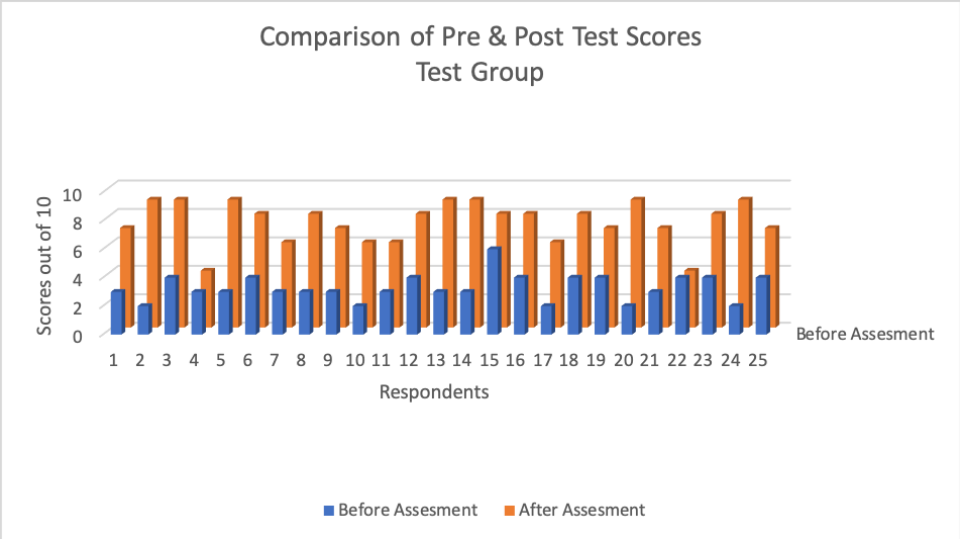


Figure 4.13: Comparison of Pre & Post Result - Test Group Bar Graph

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Before	.218	25	.004	.848	25	.002
After	.208	25	.007	.868	25	.004

a. Lilliefors Significance Correction

Figure 4.14: Shapiro-Wilk Test for Normality - Test Group

4.4 Comparison of Control and Test Groups

Analysis of Variance with repeated measure is a test statistics tool that enables researchers to conclude definitive results. This is based on analyzing the 4 types of groups based on their variance and p-value. The four types of groups in this research study are

- Control Group - Pre Test Results
- Control Group -Post Test Results
- Test Group - Pre Test Results
- Test Group - Post test Results

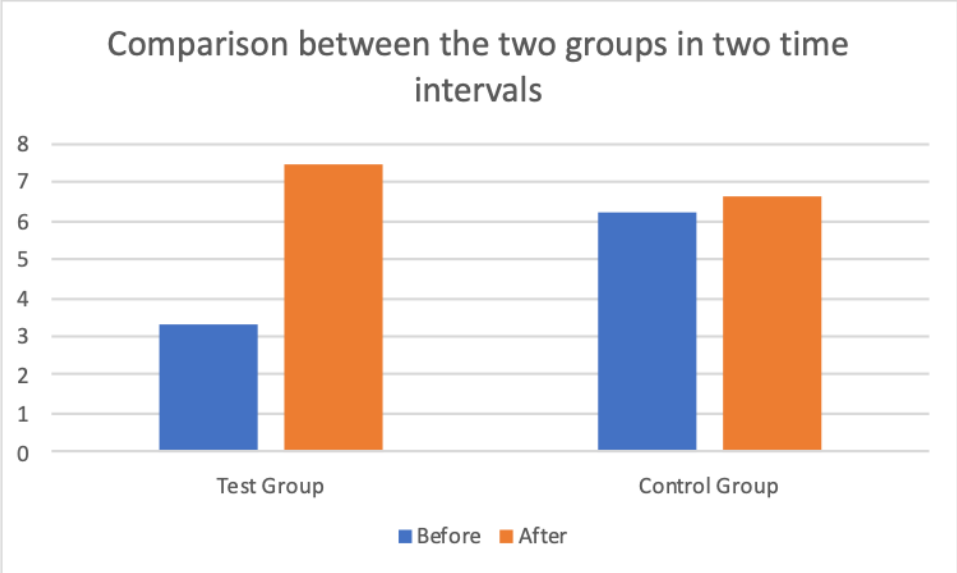


Figure 4.15: Comparison between two groups of learners in two time periods

The preliminary test results are explained in the previous sections in reference to line graphs and bar graphs. The difference between the control & test group in the intital time period has been observed, the justification observed for this difference is the level of material-proximity for the respondents in the control group. The selection of learners in control group are graduate students that have a better understanding of the subject. Since this research is concentrated on the level of improvement, this difference of scores in time-period can be neglected. The secondary analysis of data is done to provide statistical evidence with a confidence interval of 95% to prove the research hypothesis. The above listed four categories are further reduced as analysis *within the group* and *between the group*. This breakdown of two groups is because of the repeat measure factor in Anova. Ideally, the p-value from all the Anova results are considered for validation, as it describes the statistical interference between the group & within the groups. The table 4.5 represents the quality of fit between the groups and within the groups with the indication from table as "-2 Res Log Likelihood". The AIC, AICC, BIC, CAIC, HQIC represent the quality of the data collected, there is no maximum range for identifying the goodness of fit. Hence a need for fixed effects test is required. The Type III fixed effects test analyzes the goodness of fit data with respect to each group (within & between the groups) and provides a p-Value. In table 4.6 the last column represents a p-value of less than 0.001 in all factors.

Table 4.5: Fitness test

Fit Statistics	
-2 Res Log Likelihood	33.90
AIC (smaller is better)	39.90
AICC (smaller is better)	30.17
BIC (smaller is better)	35.64
CAIC (smaller is better)	38.64
HQIC (smaller is better)	32.09
Generalized Chi-Square	11.36
Gener. Chi-Square / DF	1.47

Table 4.7: By Group 1 Classification

Obs	ADJUSTMENT	adjp	time	_time	Estimate	StdErr	DF	tValue	Probt
1	Bonferroni(P<.05)	<.0001	0	1	-2.2800	0.2427	48	-9.39	<.0001

Table 4.8: By Group 2 Classification

Obs	ADJUSTMENT	adjp	Group	_Group	Estimate	StdErr	DF	tValue	Probt
2	Bonferroni(P<.05)	<.0001	T	C	-1.0800	0.2464	48	-4.38	<.0001

Table 4.6: Type III test for Fixed Effects

Type III Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr >F**
time	1	48	88.26	<.0001
Group	1	48	19.22	<.0001
time*Group	1	48	60.01	<.0001

Table 4.9: By Group 3 Classification

Obs	ADJUSTMENT	adjp	time	Group	_time	_Group	Estimate	StdErr	DF	tValue	Probt
3	Bonferroni(P<.05)	<.0001	0	T	0	c	-2.9600	0.3458	95.98	-8.56	<.0001
4	Bonferroni(P<.05)	<.0001	0	T	1	T	-4.1600	0.3432	48	-12.12	<.0001
5	Bonferroni(P<.05)	<.0001	0	T	1	c	-3.3600	0.3458	95.98	-9.72	<.0001
6	Bonferroni(P<.05)	0.0067	0	c	1	T	-1.2000	0.3458	95.98	-3.47	0.0008
7	Bonferroni(P<.05)	1.0000	0	c	1	c	-0.4000	0.3432	48	-1.17	0.2496
8	Bonferroni(P<.05)	0.1502	1	T	1	c	0.8000	0.3458	95.98	2.31	0.0228

Where,

time = Pre & Post results of both the groups

Group = Control & Test Group

Subsequent to the Type III analysis, the Bonferroni test reduces the confidence interval to check the prevalence of the goodness of fit in the data. This is done a three-step procedure and the results are tabulated in tables 4.7, 4.8 and 4.9. The above tabular columns statistically provide significant evidence to accept the hypothesis. Finally, the test for normality within the groups and between the groups reveal the normal distribution of the collected data. The table 4.10 represents the standard normality test results with a p Value lesser than 0.05. The residual plots represented in figures 4.16, 4.17, 4.18, 4.19 and 4.20 provide sufficient information on the following

- The residual error in the collected data is normal with negligible error.
- The box plots of residual by Group & time infer the means between the data and the range of residual distribution.
- The probability plot reveal the linear nature of the data with only 3 outliers that is within the acceptable limit.

Table 4.10: Normality Test Results

Tests for Normality				
Test	**Statistic**		**p Value**	
Shapiro-Wilk	W	0.96485	Pr <W	0.0090
Kolmogorov-Smirnov	D	0.106821	Pr >D	<0.0100
Cramer-von Mises	W-Sq	0.22036	Pr >W-Sq	<0.0050
Anderson-Darling	A-Sq	1.295489	Pr >A-Sq	<0.0050

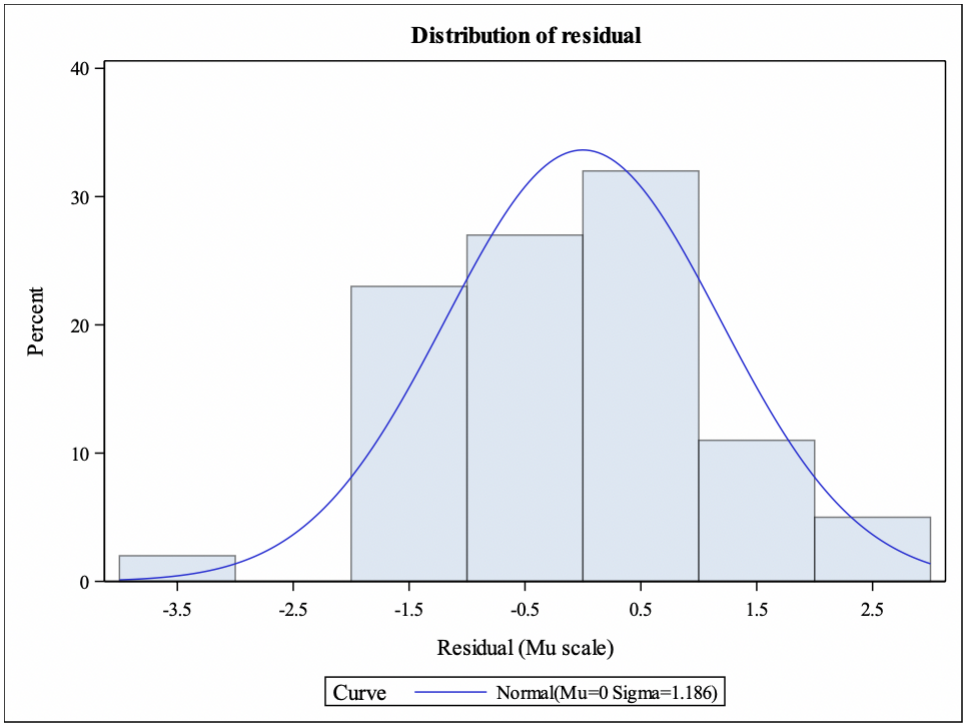


Figure 4.16: Normality Graph of the Residuals

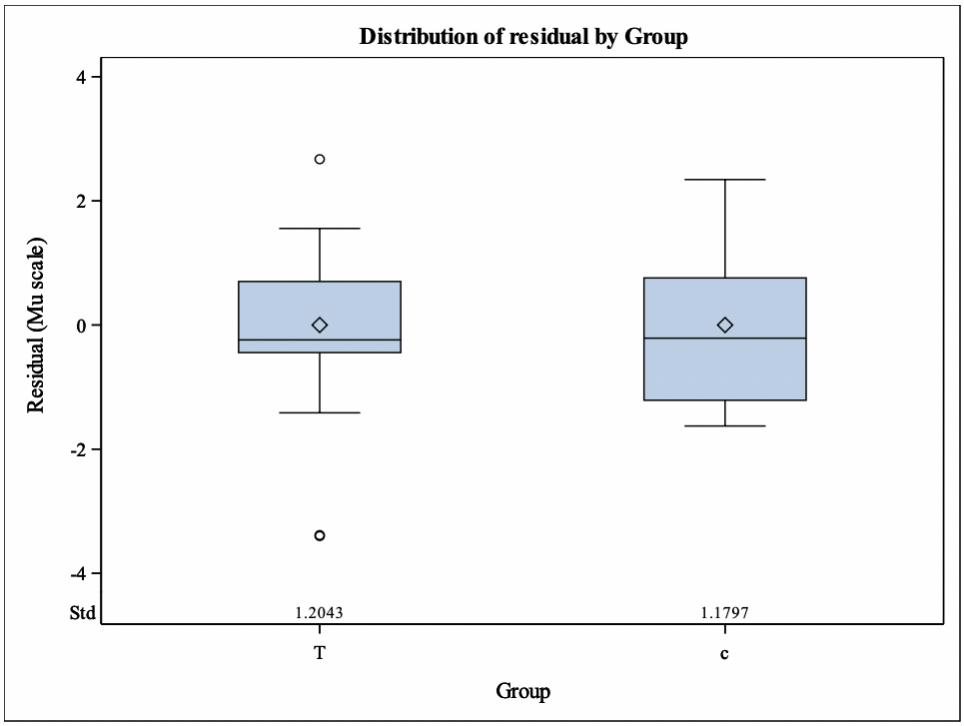


Figure 4.17: Boxplot of Residuals by Group

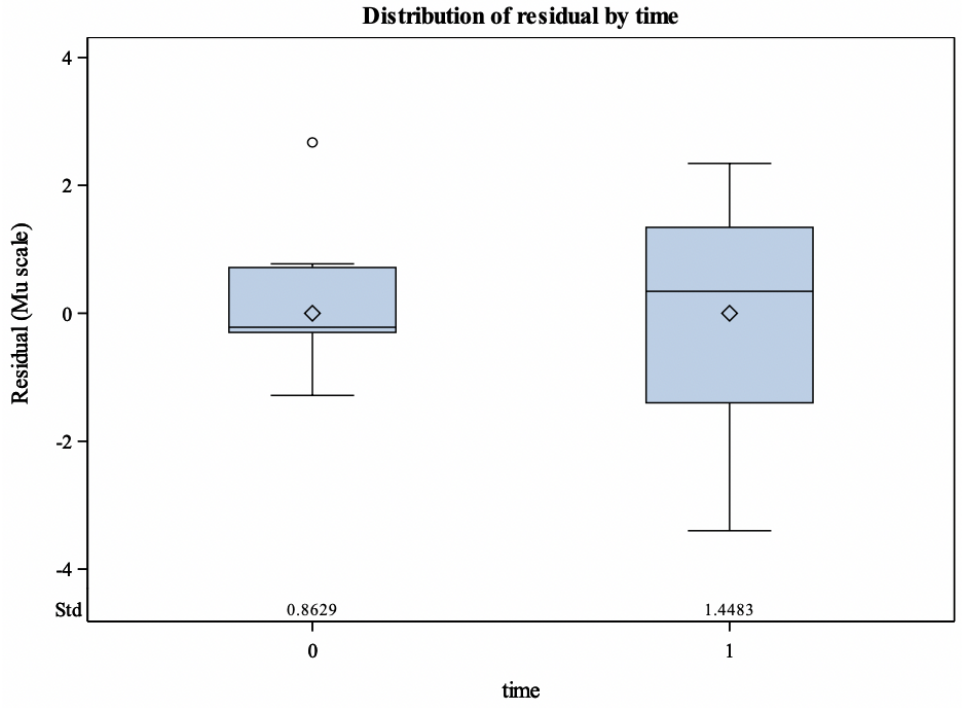


Figure 4.18: Box Plot of Residuals by Time

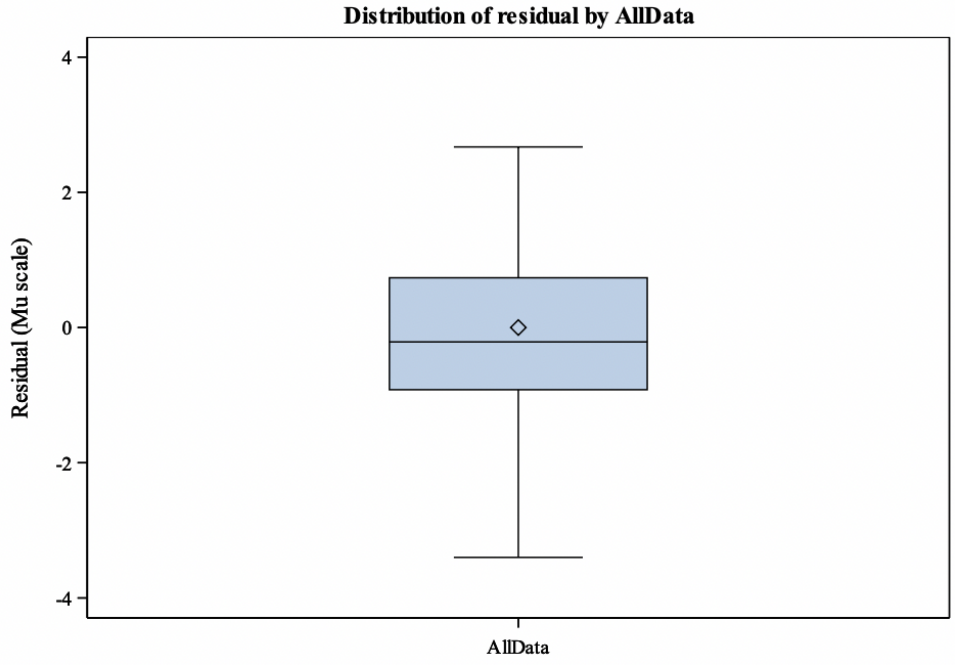


Figure 4.19: Box Plot of Residual of all Collected Data

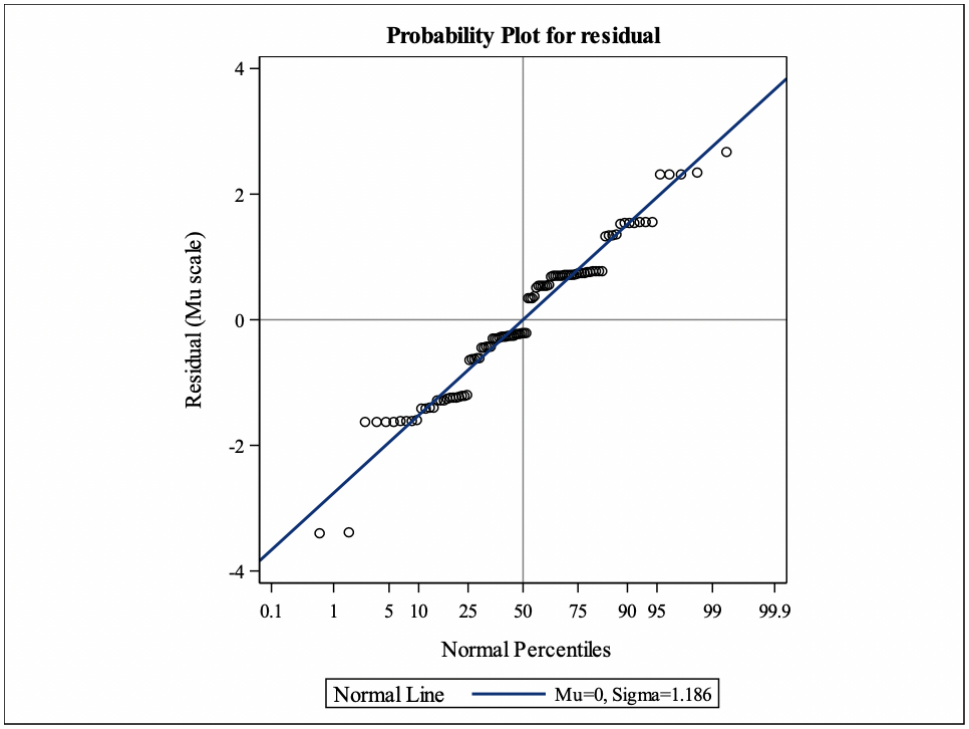


Figure 4.20: Probability of Residual for all Collected Data

4.5 Validation Survey

The research hypothesis has been proven based on the above statistical results. The vital part of this research is to validate the five identified variables and the co-relation of the variables with the proposed methodology. A survey form with *nineteen* questions, each question with a 5-point Likert scale were provided to the test group. These questions were answered by the test group immediately after the post-test questionnaire. The survey is represented in figures

Question	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Reason
1. My team will complete the task accurately when required.	1	2	3	4	5	
2. This technique is 100% efficient when done by the team	1	2	3	4	5	
3. Team members will benefit from this type of session.	1	2	3	4	5	
4. This training session create an awareness about the technique	1	2	3	4	5	
5. It was necessary to learn the same lean technique	1	2	3	4	5	
6. I have the basic knowledge to achieve the new technique	1	2	3	4	5	
7. Learning and implementing a new lean technique independently is a difficult task.	1	2	3	4	5	
8. This training session create an awareness about the technique	1	2	3	4	5	
9. This method of teaching helps students understand the lean technique easily	1	2	3	4	5	
10. I feel today's Lean topic can be easily understood	1	2	3	4	5	
11. This teaching method matched my expectation of varied learning.	1	2	3	4	5	

Figure 4.21: Survey for Validation Page 1

Question	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree	Reason
12. I will use assistive learning to learn complex techniques such as Lean technique in the future	1	2	3	4	5	
13. I have the basic knowledge to achieve the new technique	1	2	3	4	5	
14. Will this method help your team when turned into an extensive session?	1	2	3	4	5	
15. Do you feel accountable for learning this technique?	1	2	3	4	5	
16. This method of teaching will help me stay updated and compete with fellow colleagues and other team members	1	2	3	4	5	
17. Does this method help you to stay updated and in turn help your team?	1	2	3	4	5	
18. This training session helped me learn better since it was conducted in a group	1	2	3	4	5	
19. My team members have a stronger and better understanding of the concepts after working as a team.	1	2	3	4	5	

Figure 4.22: Survey for Validation Page 2

4.5.1 Pearson Correlation

The range between -1 to 1 is defined as the Pearson limit to validate linear correlation between two variables. This is significant to this research, as the variables identified have not been validated in any varied learning environment. Lack of literature is the root cause for the researchers of the study to conduct the correlation test. The data collected from the test group are tabulated in table 4.11. Each of the variable measured were not linear, this is to eliminate inconsistency in survey response. The survey questions were not provided in the order of the list, the questions were disorganized to extract the precise information from the respondent.

Table 4.11: Data Collected form the Survey

Factors	Achievement Goal	Technique Learning Value	Self - Efficacy	Maintain Attention	Cpmpe tence	Total
Respondent 1	8	13	25	14	10	70
Respondent 2	8	13	25	14	11	71
Respondent 3	9	13	24	13	12	71
Respondent 4	7	8	21	7	11	54
Respondent 5	10	12	25	14	13	74
Respondent 6	13	14	25	13	10	75
Respondent 7	12	13	26	14	10	75
Respondent 8	12	13	26	14	11	76
Respondent 9	8	12	26	14	11	71
Respondent 10	8	12	25	13	13	71
Respondent 11	7	13	26	14	12	72
Respondent 12	11	13	26	14	10	74
Respondent 13	13	13	27	13	10	76
Respondent 14	12	13	24	14	11	74
Respondent 15	13	13	26	14	13	79
Respondent 16	8	12	22	13	10	65
Respondent 17	8	12	25	14	12	71
Respondent 18	11	12	26	13	11	73
Respondent 19	13	14	26	14	11	78
Respondent 20	11	14	25	14	12	76
Respondent 21	14	14	24	13	13	78
Respondent 22	10	5	11	8	11	45
Respondent 23	8	13	26	14	11	72
Respondent 24	8	14	27	14	11	74
Respondent 25	9	13	25	14	13	74

Correlations

		Final Score	Achievement Goal	Technique Learning Value	Self - Efficacy	Maintain Attention	Competence
Final Score	Pearson Correlation	1	.474	.695	.566	.664	0.530
	Sig. (2-tailed)		.186	.000	.003	.000	.849
	N	25	25	25	25	25	25
Achievement Goal	Pearson Correlation	.474	1	.301	.122	.166	0.71
	Sig. (2-tailed)	.186		.143	.561	.427	.847
	N	25	25	25	25	25	25
Technique Learning Value	Pearson Correlation	.695	.301	1	.873	.870	0.49
	Sig. (2-tailed)	.000	.143		.000	.000	.815
	N	25	25	25	25	25	25
Self - Efficacy	Pearson Correlation	.566	.122	.873	1	.785**	.031
	Sig. (2-tailed)	.003	.561	.000		.000	.882
	N	25	25	25	25	25	25
Maintain Attention	Pearson Correlation	.664	.166	.870	.785	1	.096
	Sig. (2-tailed)	.000	.427	.000	.000		.647
	N	25	25	25	25	25	25
Competence	Pearson Correlation	0.530	0.71	0.49	0.31	.096	1
	Sig. (2-tailed)	.849	.847	.815	.882	.647	
	N	25	25	25	25	25	25

Figure 4.23: Pearson Correlation Between the Final Post Test Questionnaire & the Variables

The data collected from the survey is finally analyzed for only Pearson correlation, this is performed to reduce the complexity of the research. The results are represented in figure 4.23. The red box highlighted in the image is the correlation between the final post-test questionnaire answers and each of the identified variables. Since Pearson's limit is between -1 to 1, a correlation value of 0.30 and above is considered to be acceptable. Correlation values above 0.50 are considered to be highly correlated in behavioral research studies.

A linear pattern of correlation is observed from the above table and figure. Hence, a further explorative regression analysis to predict the characteristic of each variable with respect to the final score. Performing the linear regressing takes into the factors into account and substituting in the formula below

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5$$

Based on the results displayed in figures 4.24, 4.25 and 4.26 the following statistical conclusion can be provided

$$y = 3.373 + 0.79X$$

Where

X = Technique Learning Value

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.695[a]	.482	.460	1.083	.482	21.444	1	23	.000

a. Predictors: (Constant), Technique Learning Value

b. Dependent Variable: Final Score

Figure 4.24: Descriptive Results from the Linear Regression Model

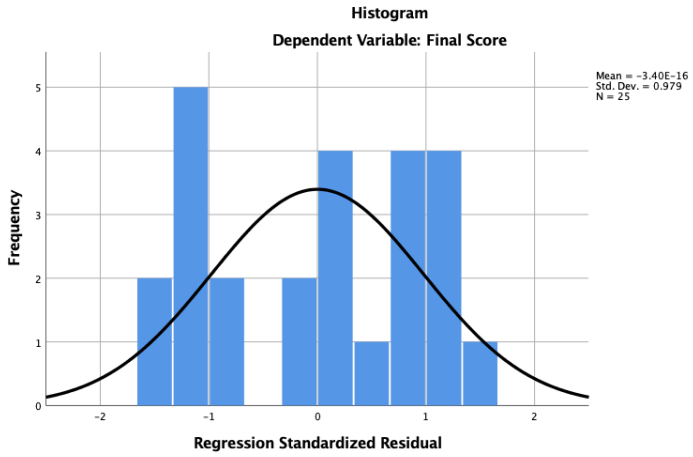


Figure 4.25: Normal Distribution Graph of the Variables

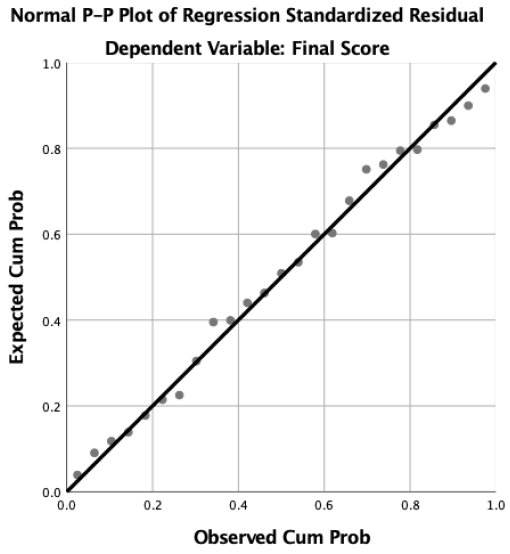


Figure 4.26: P-P Plot of the Residuals

4.6 Summary

The hypothesis of the research was provided in Chapter 3 that interactive classroom environment increases the learning outcome in adult lean training program. The required variables to design an interactive training session were identified and experimented on a group of adults. Further into analysis, it is evident that an interactive learning environment increases the learning outcome of adults in lean training session. The validation survey also showed the test group identified the presence of each variable in the VLE training methodology.

Chapter 5

Conclusion and Future Work

The motivation for this research was to increase the adult learning outcome in lean training by providing an interactive learning environment. Throughout the previous chapters, the background and the effects of interaction in classroom and problem statements were discussed, The literature with respect to the current and proposed methodologies were reviewed. A cause specific methodology was identified by valuing adult learning variables and thus identified training methodology (VLE) has been experimented among adult demographics, the results have been compared with the traditional training program for adults and displayed. This chapter of the thesis summarizes the noteworthy results of the research and discusses the future work.

5.1 Summary of the Research Study

The beginning of the research study is based on the problem statement that concentrates on lack of interaction withing learners in lean training. Hence, the variables required for an interactive adult training session are identified. Subsequent to the identification, suitable learning environment that encompasses a training methodology (TBL) and a study tool (PH) are selected. Since this selection process is completely revolutionary, a traditional learning environment (Co-operative learning) is selected for comparison purposes. Following this approach leads to developing a course module to test the various learning environments. Based on this approach and conduction of experiments, the effect of interaction within

the learners between the two groups of learner was analyzed. The findings from the data collection reveal an increase in learning outcome from the VLE based group. This result has major implication in lean implementation, as the problem identified in this research is directly related to employee engagement. In this research, statistical proof for the effect of interaction is reviewed, but the various variables aiding in an intractive learning environment are also validated. This validation is done by considering metrics derived from variables accountable for adult interaction in classroom. Based on the research finding, It is also observed that smaller groups of learners indulge in active participation and discussion with their respective teammate in an unconscious manner. This forms the major reason for developing cognitive skills within a short duration. The durations being short is advantageous, as the attention span of the learner is keen.

Lean Manufacturing is analyzing the variation in customer demand and implementing a pull system, but not concentrating on equiping the workforce provides a source of barrier for lean implementation. Throughout the research, the key differences between Varied Learning Environment (VLE) and Co-Operative Learning (CL) have been analyzed with respect to the effectiveness of the learning outcome. In the previous chapters the effect of interaction within learner has been proved significantly positive by using VLE. Futhermore, interactions must take place before implemeting a new lean technique as the classroom environment is more condusive than the manufacturing facility and reduces work-pressure from the employee. Finally, thorough understanding of this research study helps to decrease lean implementation failure due to employee engagement.

5.2 Organizational Implications

The novelty of this research study is identification of the variable suitable for an interactive adult learning environment and provision of a Varied Learning Environment. Moreover, this research study compares the proposed VLE methodology to a standard adult training methodology such as CL to provide statistical evidence on the increase in adult learning outcome. This research provides required information regarding team formation & the efficient use of pyramid hologram alongside their utility in lean training. The suitable

variables for an interactive learning environment and their linear regression analysis help management take precise training decisions.

5.3 Limitations and Future Work

- This research study is based on adults on a specific set of variables accountable for interaction.
- The analysis of this research was carried out with the minimum required population. however, increasing the population may have an effect of overall learning outcome.
- This research does not study the effect of lean implementation after successful VLE training program.

The definitive path leading beyond this research study is the ability to trace the effect of each individual variable in effective learning outcome. This study has provided an overall validation for the VLE, but the effect of each variable in lean training and the methods to incorporate to increase or decrease the degree of that variable in the methodology can be helpful in getting a better understanding of the employees currently in the workforce. Likewise, the effect of the VLE prior to lean implemetation could be done to aid organizations in lean transition.

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Appendix

A Institutional Review Board



THE UNIVERSITY OF
TENNESSEE
KNOXVILLE

November 09, 2018

Rupy S Sawhney,
UTK - College of Arts & Sciences - Biological Sciences

Re: UTK IRB-18-04723-XP
Study Title: Team based learning of Lean manufacturing using 3D Hologram

Dear Rupy S Sawhney:

The UTK Institutional Review Board (IRB) reviewed your application for the above referenced project. It determined that your application is eligible for expedited review under 45 CFR 46.110(b)(1), Category 7. The IRB has reviewed these materials and determined that they do comply with proper consideration for the rights and welfare of human subjects and the regulatory requirements for the protection of human subjects.

Therefore, this letter constitutes full approval by the IRB of your application (version 1.2) as submitted, including:
Survey Consent Elements (Statement) v1.1
Waiver of Documentation of Informed Consent 45 CFR 46.117(c)(2)
FinalSURVEY_TBL v2.1
Pre survey v1.0
The above listed documents have been dated and stamped IRB approved. Approval of this study will be valid from 11/09/2018 to 11/08/2019.

In the event that subjects are to be recruited using solicitation materials, such as brochures, posters, web-based advertisements, etc., these materials must receive prior approval of the IRB. Any revisions in the approved application must also be submitted to and approved by the IRB prior to implementation. In addition, you are responsible for reporting any unanticipated serious adverse events or other problems involving risks to subjects or others in the manner required by the local IRB policy.

Finally, re-approval of your project is required by the IRB in accord with the conditions specified above. You may not continue the research study beyond the time or other limits specified unless you obtain prior written

approval of the IRB.

Sincerely,

Colleen P. Gilrane

Colleen P. Gilrane, Ph.D.
Chair

Institutional Review Board | Office of Research & Engagement
1534 White Avenue Knoxville, TN 37996-1529
865-974-7697 865-974-7400 fax irb.utk.edu

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B Consent Letter

Consent for Research Participation

Research Study Title: Team based Learning of Lean Manufacturing using 3D Hologram

Researcher(s): *Aravind Satyanarayanan*, University of Tennessee, Knoxville

Dr. Rupy Sawhney, University of Tennessee, Knoxville

We are asking you to be in this research study because you have the industry experience and working knowledge on implementing something new in your organization for improvement purposes. You must be age 18 or older to participate in the study. The information in this consent form is to help you decide if you want to be in this research study. Please take your time reading this form and contact the researcher(s) to ask questions if there is anything you do not understand.

Why is the research being done?

The purpose of the research study is to evaluate the benefits of Team based Learning of Lean Manufacturing using a 3D Hologram as a study tool.

What will I do in this study?

If you agree to be in this study, you will complete a pre and post survey questionnaire. The survey includes questions about distinct variables that constitute towards your learning outcome and should take you about *10 minutes* to complete. Please answer based on your choice and write your opinion on the open-ended spaces

Can I say "No"?

Being in this study is up to you. You can stop up until you submit the survey. After you submit the survey, we cannot remove your responses. Being in this survey will not affect your grades, your relationship with the instructor or your standing in The University of Tennessee in any way.

Are there any risks to me?

From the researcher's perspective, there are no foreseeable risks involved in this study. But even if you slightly feel uncomfortable in answering a question, you can please contact the researchers.

Are there any benefits to me?

We do not see any immediate benefits to you from this study. But this study is helpful in gaining insights to teach Lean manufacturing for people working for organizations and people that are responsible for decision making.

What will happen with the information collected for this study?

The survey is anonymous, and no one will be able to link your responses back to you. Please do not include your name or other information that could be used to identify you in your survey responses. Information collected for this study will be published and possibly presented at scientific meetings.

Who can answer my questions about this research study?

If you have questions or concerns about this study, or have experienced a research related problem or injury, contact the researchers, **asatyana@vols.utk.edu** and/or **sawhney@utk.edu**

For questions or concerns about your rights or to speak with someone other than the research team about the study, please contact:

Institutional Review Board
The University of Tennessee, Knoxville
1534 White Avenue
Blount Hall, Room 408
Knoxville, TN 37996-1529
Phone: 865-974-7697
Email: utkirb@utk.edu

Statement of Consent

I have read this form, been given the chance to ask questions and have my questions answered. If I have more questions, I have been told who to contact. By completing and returning the survey, I understand that I am agreeing to be in this study. I can keep a copy of this consent information for future reference. If I do not want to be in this study, I do not need to do anything else.

Vita

Aravind Satyanarayanan was born in Chennai, India on the 21st of December, 1994. He is the son of Late. Satyanarayanan and Anuradha Satyanarayanan. He completed his undergraduate degree in Electrical and Electronics Engineering from Anna University, India. In the year 2016, he was admitted into the Department of Industrial and Systems Engineering Master's Program. During the course of his graduate studies, he has served as the Graduate Research & Teaching Assistant and accomplished his Master's degree in July 2019.