THE EFFECT OF GAME-BASED LEARNING IN LEAN PRODUCTION AND LEAN SIX SIGMA TRAINING

A THESIS
SUBMITTED TO THE DEPARTMENT OF
INDUSTRIAL ENGINEERING
AND THE GRADUATE SCHOOL OF ENGINEERING AND SCIENCE
OF ABDULLAH GUL UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF SCIENCE

By
Burcu KURT ÖZDEN
August 2019

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SCIENTIFIC ETHICS COMPLIANCE

I hereby declare that all information in this document has been obtained in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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M.Sc. Thesis titled “The Effect of Game-Based Learning in Lean Production and Lean Six Sigma Training “has been prepared in accordance with the Thesis Writing Guidelines of the Abdullah Gül University, Graduate School of Engineering & Science.

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THE EFFECT OF GAME-BASED LEARNING IN LEAN PRODUCTION AND LEAN SIX SIGMA TRAINING

Burcu Kurt Özden
MSc. in 2019
Supervisor: Dr. Muhammed SÜTÇÜ
Dr. Elif BENGÜ

August 2019

Nowadays, business leaders and managers are highly concerned about the sustainability of their success. In the business world, there are many leaders, companies, products, and even industrial areas that have a short-term reputation.

What is the key to be at the top constantly and to keep the competition ability at a high level in such an environment? Most small and big companies try to find answers to this question. For this reason, they try to implement different strategies and innovations to improve their process and standards. Accordingly, we face the Lean Production System, Six Sigma, and Lean Six Sigma concepts.

Japanese employees of Toyota Company developed the Lean Production system after the Second World War. It is a methodology "that is based on the elimination of all wastage in the enterprise and respect for human,"

The leading position of Japanese companies with their works has attracted the attention of American companies in particular. The Six Sigma method, which includes quality improvements to meet the expectations of the customer, was implemented under the leadership of Motorola, which was an American Company. In the 2000s, the Lean Six Sigma management system, which simultaneously used Lean Production techniques with Six Sigma techniques, has emerged. Lean Six Sigma is a management philosophy that aims to reduce waste, increase productivity, and improve product quality in line with customer demands and expectations.

One of the most critical elements in Lean Production and Lean Six Sigma systems is to respect human beings and to value people. For Lean Production and Lean Six Sigma systems to be successful, when these techniques are no longer mandatory and become a company culture, success is sustainable, the right techniques should be provided with the right training for these systems to be able to become the culture. Since companies implementing Lean Production and Lean Six Sigma system cannot make the right choice in training and cannot make their employees adapt to this culture, new improvement systems can cause misfortune of the companies. This study, which aims to solve the difficulties of the companies in the selection of training with a technical point of view, will contribute to both the applications in the production facilities and the academic literature.

In this study, the Lean Production System, Six Sigma Method, Lean Six Sigma Method are explained in general, new lean game is designed and the effect of using game-based learning techniques on Lean Production and Lean Six Sigma training is discussed.

The aim of this thesis is:

1. To analyze the effects of game-based learning in training that use Lean Production and Lean Six Sigma management system on learning and

2. To guide the companies on selecting the right training techniques.

Key Words: Lean Six Sigma, Training, Game-Based Learning, Lean Game, Gamification

ÖZET

YALIN ÜRETİM VE YALIN ALTI SİGMA EĞİTİMLERİNDE OYUN TABANLI ÖĞRENMENİN ETKİSİ

Burcu KURT ÖZDEN
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Ağustos-2019

Günümüzde iş dünyası liderlerinin ve yöneticilerinin en çok endişe ettiği konu başarının sürdürülebilirliği konusudur. İş dünyasında şöhreti çok kısa süren birçok lider, şirket, ürün ve hatta sanayi alanları bulunmaktadır.

Böyle bir ortamda sürekli zirvede kalmanın ve rekabet yeteneğini üst seviyede tutmanın anahtarı nedir? sorusu büyük ya da küçük ölçekli tüm işletmelerin cevabını aradığı sorudur. Bu nedenle firmalar süreçlerini iyileştirmek için farklı stratejileri ve yenilikleri uygulamaya çalışmaktadırlar. Bu doğrultuda karşımıza Yalın Üretim, Altı Sigma ve Yalın Altı Sigma kavramları çıkmaktadır.

Yalın Üretim Sistemi, ana hatlarıyla, II. Dünya Savaşı sonrası Japonların ve özellikle Toyata çalışanlarının geliştirdikleri, işletmedeki tüm israfların ortadan kaldırılması ve insana saygıyı temel alan bir metodolojiler bütünüdür.

Japon firmalarının çalışmaları ile lider konuma gelmeleri, özellikle Amerikan firmalarının dikkatini çekmiştir. Bu doğrultuda müşterinin beklentilerini karşılayacak kalite iyileştirmelerini içeren Altı Sigma yöntemi, bir Amerikan Şirketi olan Motorola'nın liderliğinde, uygulanmaya başlamıştır. 2000'li yıllarda Altı Sigma teknikleri ile eş zamanlı olarak Yalın Üretim tekniklerinin de kullanıldığı "Yalın Altı Sigma" kavramı ortaya çıkmıştır. Yalın Altı Sigma, müşteri talep ve beklentileri doğrultusunda, israfı azaltmayı, verimliliği arttırmayı ve kaliteyi artırmayı amaçlayan yönetim sistemidir.

Yalın Üretim ve Yalın Altı Sigma sistemlerinde en önemli unsurlardan biri insana saygı ve insana değer vermektir. Yalın Üretim ve Yalın Altı Sigma sistemleri zorunluluk olmaktan çıkıp firma kültürü haline geldiğinde başarı, sürdürülebilir olmaktadır. Bu

sistemlerin kültür haline gelebilmesi için doğru teknikler ile doğru eğitimlerin verilmesi gerekmektedir.

Yalın Üretim ve Yalın Altı Sigma sistemini uygulayan firmalar eğitim seçiminde doğru tercihi yapamadıkları ve çalışanları bu kültüre adapte edemedikleri için yeni iyileştirme sistemleri firmaların felaketine sebep olabilmektedir. Firmaların eğitim seçiminde yaşadıkları zorlukları teknik bir bakış açısı ile çözümlemeyi hedefleyen bu çalışma hem üretim tesislerindeki uygulamalara hem de akademik literatüre katkıda bulunacak niteliktedir.

Bu çalışmada Yalın Üretim Sistemi, Altı Sigma Yöntemi, Yalın Altı Sigma Yöntemi genel hatlarıyla anlatılmıştır, yeni bir yalın oyun tasarlanmıştır ve Yalın Üretim ve Yalın Altı Sigma eğitimlerinde oyun temelli öğrenme tekniklerinden biri olan yalın oyunların kullanılmasının öğrenmeye etkisi analiz edilmiştir.

Bu tezin amacı:

1. Yalın Üretim ve Yalın Altı Sigma yönetim sistemini kullanan işletmelerde oyun temelli öğrenmenin etkilerini analiz etmek ve

2. Firmaları doğru eğitim tekniklerini seçme konusunda yönlendirmektir.

Anahtar Kelimeler: Yalın Altı Sigma, Eğitim, Oyun Temelli Öğrenme, Yalın Oyun, Oyunlaştırma

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To My Family

Chapter 1

Introduction

1.1 Purpose of the Study

Lean Production and Lean Six Sigma systems are based on respecting human and respecting opinions. For Lean Production and Lean Six Sigma systems to be successful, these techniques should not be implemented as an obligation. When these improvement systems become a company culture, success will be sustainable. It has to become the company culture out of obligation for Lean Production and Lean Six Sigma system to be successful. To make this possible, appropriate training should be given with appropriate techniques.

Many firms have difficulty in selecting training techniques and have difficulty in measuring the learning outcomes of their employees [1]. Instead of checking the quality of the training methods or the method of delivery, companies usually put the blame on Lean Production and Lean Six Sigma management systems for the the reason of the failure.

One of the aims of this study is to analyze the effects of lean games which are actively used in Lean Production and Lean Six Sigma management system training on learning. This study also aims to help firms to make the right decisions in the selection of the training.

The study focused on the following research questions:

1. How do the choice of Lean Production and Lean Six Sigma training affect learning?

a) How do the standard training in Lean Production and Lean Six Sigma affect learning?

b) How do lean games in Lean Production and Lean Six Sigma training affect learning?

c) How does new designed interactive Lean Game in Lean Production and Lean Six Sigma training affect learning?

2. How do key performance indicators of new designed interactive Lean Game change?

1.2 Significance of the Study

Lean Production and Lean Six Sigma management systems are the systems that have been successful throughout the years, and that aimed at continuous improvement in both production and service sectors.

By providing the same Lean Production and Lean Six Sigma training to the employees who have different backgrounds, characteristics, and abilities, we should not expect the achievement of success in building the philosophy of continuous improvement.

Companies provide different kinds of training called improvement, but they do not improve training content. They contradict themselves. Training cannot be improved if it is not measured or evaluated. Companies that realize the continuous improvement of their trainings can step forward.

This study focuses not only on the effects of the training techniques on learning but also the facilitation of the decision-making process when selecting a training techniques to apply Lean Production and Lean Six Sigma results for the improvement of the training.

1.3 Motivation for the Study

During my university studies, we had a chance to visit Toyota factory in Turkey. During that technical visit, I learned about Toyota Production System, which is one of the most advanced Lean Production systems in the world. Since then, I have started to research about this management philosophy, which is based on respecting human and waste disposal.

The university lectures and the projects we worked on during the courses strengthened my knowledge more on Lean Production. However, something was missing. I couldn't have found the missing part until I took the training titled "Learning from Kaizen Master" by K. Ozawa Sensei, who once worked in Toyota companies, and talked about how to create a Lean Production culture beyond the classic Kaizen approach and how to ensure the employees' sincere participation in Kaizen's work. In the last part of the training, game-based training was given. Over time, I discovered the impact of learning Lean Production by a lean game, which is also the game-based learning technique that was used in the last part of the training. After this discovery, I continued to study and research the lean games.

I started providing Lean Production and Lean Six Sigma training when I graduated and started working as a Lean Office Engineer at a private company in Turkey. The methods I used to measure the improvement of the trainings were insufficient to measure the impact of the trainings.

I needed to measure whether the lean games, one of the game-based learning techniques, had any benefit and effect on learning. Because if we could not measure the effectiveness of training on employees, the improvement systems could have failed.

Thesis subject of this study has been determined as a result of practice and training given for years. In order to overcome the faults and disadvanteges in other trainings, new lean game has been designed.

The focus of this thesis is to demonstrate the positive outcomes of lean game training, one of the game-based learning techniques, for on learning. Game-based learning also includes entertainment elements and can create dynamism at work. Moreover, the study will be carried out to assist companies and researchers that implement or will start to implement Lean Production and Lean Six Sigma management systems, in the process of selection of the training and its improvement.

Chapter 2

Literature Research

2.1 Lean Production

Lean Production is not a new phenomenon. The origin of Lean Production belongs to Japan, specifically to the Toyota Motor Company [2]. Lean thinking has long history and is contributed by different cultures. It is derived from the Toyota Production System, Henry Martin Ford, and other predecessors [2].

Starting in 1910, Henry M. Ford and Charles E. Sorensen set up the first comprehensive production strategy [3]. Henry M. Ford and his right-hand man Charles E. Sorensen used all the elements of the productions system and arranged them in a continuous system for manufacturing the Model T automobile. Ford has been very successful with the black Model T and line production system. The production time of an automobile was reduced from 13 hours in 1912 to 1.5 hours in 1914 with the assembly line designed by Ford [4]. This success has quickly made him one of the richest men in the world. Ford is considered by many to be the first implementer of just-in-time and Lean Production.

In his book "Today and Tomorrow," which belongs to Henry M. Ford, "The industry's last point is to save the human mind and body from the hardship and exhaustion of their tough working conditions and to produce good products at low cost."[5].This shows that Ford and his team had no goals in true sense of making workers work more and making them slaves of the machine [3, 5 and 6]. When the competition conditions began to change, Ford's famous system began to breakdown [7]. The words show that Ford is not open to change "Any customer can have a car painted any color that he wants so long as it is black" [4, 8].

At General Motors, Alfred P. Sloan took more pragmatic approach. He developed business and manufacturing strategies for managing huge enterprises and dealing with a variety [9, 10]. General Motor's model diversity was more interesting than Ford's black-colored car. By the mid-1930s, General Motors passed Ford in the domination of the automotive market [10] .General Motor's color, type, and model diversity were prominent. The rise of General Motors brought diversity to car models [3, 10].

While the American automotive industry was developing rapidly, Sakichi Toyoda put the foundations of The Toyota Group in Japan. [11] He was working on weaving looms. He developed important concepts like five whys, Jidoka, automation [11]. He succeeded tremendously by, improving both productivity and work efficiency. Toyoda's loom with jidoka became very popular in Japanese weaving companies [11]. In 1910, Sakichi Toyoda visited the United States. The automotive sector attracted his attention during this visit. So, The Toyoda family took the first step into the automobile industry. He encouraged his son Kiichiro Toyoda to enter into the automobile industry [12, 13, and 14].

Kiichiro Toyoda was the founder of the Toyota Motor Corporation in 1937 [6]. He applied the philosophy of "Just in Time" in automotive production. By practicing the philosophies of "Daily Improvements" and "Good Thinking, Good Products," the Toyota Production System has evolved into a world-renowned production system. Kiichiro's greatest supporter was Taiichi Ohno.

In 1945, Taiichi Ohno became the head of the production department of Toyota Motor Company [15]. Taiichi Ohno was the architect of The Toyota Production system and a symbol of Japan's manufacturing resurgence after the Second World War.

Toyota had to produce military vehicles during the Second World War. After the war, Toyota started working to produce its own automobile and to increase its efficiency. After the war, Sakichi's son, Eiji Toyoda and Taiichi Ohno went to America, and with the philosophy of Genchi Genbutsu, they adapted his observations to the automotive industry [3, 12, and 16]. The aim of Genchi Genbutsu was "going to the source and to find the facts" [3] .Taiichi Ohno was capable of creating a system linking the two pillars of the TPS (Jidoka and Just-in-time) with the Ford assembly line [16]. Under these conditions, the goal of the Japanese was not to imitate Fordist production. They intended to build a better system.

Toyota does not deny that much has been learned from the American automobile empire [3]. Japan has been successful in importing and implementing improvement practices [3]. Instead of making too much production, Toyota aimed to produce more flexible, better quality, and less costly production. The three most essential elements of production are labor, capital, and land. There was very little capital in Japan because of the war. The land was limited. There was only one thing open to healing, and that was the labor. The important thing was to use the workforce properly [17]. As a result, Toyota has always given importance to human respect. Toyota soon discovered that factory workers had far more to contribute than just muscle power. Thus, quality circles and Kaizen principles began [14].

Zambanini reported that “application of statistical control came later as a result of World War production methods, and were advanced from the work done by W. Edwards Deming, and Dr. Joseph M. Juran” [18]. They have worked on total quality management. At the beginning, these statisticians won several transformations in the United States. Zambanini reported that “However, managers in Japan embraced their ideas enthusiastically.” [18]. Zambanini reported that “General Douglas MacArthur, the Supreme Commander of the Allied Powers, invited Deming to Japan in 1947 to assist in preparing the 1951 census, a census that had, as one of its functions, to determine the destruction caused by World War II.“ [18]. The Japanese Union of Scientists and Engineers (JUSE) sought out statistical process control (SPC) experts. That same year, they brought Deming to help them train hundreds of Japanese managers [18]. JUSE also introduced the Deming Prize in 1950, an indication of the importance with which the Japanese saw Deming’s teachings [18, 19]. Deming saw quality management as a process, and it has brought the PDCA (Plan-Do-Check-Act) cycle into a philosophy of quality [20]. Deming’s PDCA was used in the improvement of the Toyota Production System. Taichi Ohno reported that “Ishikawa is one of the leaders contributing to total quality management, Deming, and Juran all made major contributions to the quality movement.” It culminated in team development and cellular manufacturing [12].

Toyota was developing rapidly with the Toyota Production System and was the created the Lean Production System in 1973, when the oil crisis entered the world's agenda [16]. Japan survived the 1973 oil crisis quickly. Due to the oil crisis, fuel prices increased, and customers preferred Japanese cars which had not been preferred before.

The definition of “Lean Production” was first made by John Krafcick, a researcher at Harvard University [21]. The reason why Krafcick used the lean term was that the new system used fewer resources than Fordist production [15, 21]. In their book “The Machine That Changed the World” Womack, Jones and Roos, combined a comparative study of Japanese, American, and European automotive assembly plants and came up with a new phrase lean. “Lean Production” was new phase in their book [14]. This study is one of the most important works of Lean Production. In this study, Lean Production is defined as the production system where the elements like error, cost, stock, labor, etc. are minimized, and waste is destroyed [14]. The key to success in Lean Production is to eliminate waste. [22] Taiichi Ohno defined waste as "an activity that consumes resources, but non-value-added" [12]. Henry M. Ford defined waste as "everything that does not add value" [23, 24, and 25]. Ohno, Womack and Jones primarily describe seven wastes of Lean Production. [3, 12, 24, and 26].

The Seven Wastes of Lean Production are [3, 27 and, 28];

- Transport
- Inventory
- Motion
- Waiting
- Over-Processing
- Overproduction
- Defects

2.1.1 Principles of Lean Production

Lean Production is to simplify production in accordance with some principles. In line with these principles, continuous improvement activities are becoming standard.

The basic principles of Lean Production are given below; [26, 29].

- Define Value
- Value Stream
- Create Flow
- Establish Pull
- Seek Perfection

Define Value: Value is what the customer is willing to pay for [26, 29, and 30].

Value Stream: The value Stream is to define all activities that contribute to these values by considering the value defined by the customer [31].

Create Flow: value interrupted throughout all processes the flow and the elimination of wastes [3, 26].

Establish Pull: Production in accordance with the demand of the customer [24].

Seek Perfection: Continuous improvement of this value should be provided. It is impossible to achieve perfection, but it is possible to approach perfection [24, 32].

2.1.2 Lean Production Techniques

2.1.2.1 5S

5S, which is the basis of Lean Production techniques, is a workplace arrangement technique. At first, it is simple, but in fact, it is a difficult technique.

5S consists of 5 steps starting with the letter ‘S’ [33]. These steps are listed below.

- Sort (Seiro)
- Set in order (Seiton)
- Shine (Seiso)
- Standardize (Seiketsu)
- Sustain (Shitsuke)

1. Sort (Seiro): It is the first step of 5S systematics. In this step, the materials are classified as necessary and unnecessary [33]. The aim is to remove unnecessary materials in the work areas. Cards, which are called red tags, are applied to unnecessary materials and inappropriate situations [34, 35]. Red tags can be hung on unnecessary materials, and also can be hung on sources of pollution, oil leaks, or damaged machine parts [34]. Materials with a red card are moved to the red area. The red area is the name given to the 5S collection area in 5S systematic. Materials in the red area are removed in a short time.

2. Set in order (Seiro): This step is the step in which the required materials are classified according to the frequency of use in the work area where there are no unnecessary materials. Suzuki reported that there should be 'a place for everything and everything in its place' is the notion that everything should have somewhere to be stored and material should return when not in use [24]. In this step, hourly, daily, weekly, or annual usage, amounts of materials are examined. Materials that are frequently used according to the frequency of use are placed in close areas. Less commonly used materials are placed in slightly more remote areas. At the same time, inventory quantities are determined. In this step, it is aimed to reduce material search time and eliminate waste of motion.

3. Shine (Seiso): 5S systematics are generally perceived as cleaning. Cleaning is a result when 5S studies are successful. At the beginning of the 5S operation, only a large cleaning operation is performed. Then the root causes of the sources of pollution are detected, and the source of pollution is destroyed [24, 34]. The aim is to keep the work areas clean without contamination, without the need for large cleaning preparations are made for visual cleaning forms and cleaning checklists to suit the working areas and the machine park.

4. Standardize (Seiketsu): After the first three steps of 5S are completed, this step is started. Standardization is the establishment of standards, improvements, and control methods to ensure the sustainability of achievements in the first three steps [24]. Taiichi Ohno once noted, “Without standards, there can be no Kaizen.” [3, 36]. After 5S, one cannot imagine how anyone can do Kaizen without standards. In this step, studies are carried out to help standardization such as visual cleaning charts, work order, periodic check charts, addressing, labeling, and color standardization.

5. Sustain (Shitsuke): Sustaining, is the step of turning the system into a habit, developing activities, and ensure one's continuity. Everyone should supervise their own work area and equipment. Controls and inspections should be short and standard. However, in the Toyota system, the last step is not used as standard jobs are audited [33]. The 5S system only succeeds with the adoption of 5S by employees. In this step, the studies are conducted on the appraisal systems and employee training.

Many studies have been done on the application of the 5S system, success factors, and methods.

Warwood and Knowles, in their study; examined the 5S applications of enterprises in England [37]. In this study, it is mentioned that the 5S system contributes positively to occupational health and safety. They stated that the key to success in the 5S systematics is the harmony between theoretical knowledge and implementation [37]. Rahman et al. conducted surveys on two firms that applied 5S system. As a result of this study, they stated that 5S barrier was communication and employee training [38]. 5S work is an essential factor in ensuring the communication of 5S teams. Creating 5S teams and creating synergy simplifies the solution of problems [39]. Too much work is required to ensure the success of the 5S systematic because the change of working principles is very difficult. However, these studies will result in benefits like quality, safety, and increase of motivation [40]. According to the findings of Ho, the 5S systematics in Hong Kong developments in the quality of products have been observed in many companies [40].

As a result of the studies and implementations, 5S does not only mean cleaning. It is a system that provides benefits in many areas, such as quality, cost, and occupational health and safety. In order for the 5S systematics to be successful, it is necessary to have sustainability, good communication, and good training.

2.1.2.2 Just in Time Production

Just in time (JIT) is the ability to produce a product with the requested features at the desired time and the desired amount [26]. It is also a production system that affects all departments and ensures increasing of productivity [41, 42].

Just in Time Production, which was selected by Kiichiro Toyoda as a way of differentiation from the American automotive industry in the 1930s was implemented by Taiichi Ohno in the 1950s [3]. In this system, after receiving the customer request, these demands are leveled, continuous flow is created, and production is done according to the takt time [43, 44, and 45]. “Takt time" is a German word, which means tempo created by the orchestra manager with the baton [46]. Just in Time Production system, on the other hand, is a measure for linking the speed of production or service provided with the demand of a customer. Since takt time is linked to demand, practically the customer determines the takt time. Therefore, customer demand has great importance in the calculation of takt time [47].

Just in Time Production aims stockless work and makes problems visible [48, 49]. There are many different definitions for Just in Time Production. In general, it is defined as stockless production. However, Just in Time Production is a more comprehensive Lean Production System. Just in Time Production, in addition to stockless work, continuous improvement is made by taking into consideration the quality, customer satisfaction, flexibility, low resource utilization, and the shortest time [50]. Just in Time Production can be summarized as “sell first, then produce with stockless production just in time and in good quality.” [51, 52].

2.1.2.3 One-Piece Flow

In Lean Production, one-piece flow is that each workstation produces a product in takt time and moves it to the next workstation [21]. One-piece flow has various benefits [53, 54]. With one-piece flow, line imbalances, wastes, and bottlenecks are made visible. Waiting time, transportation time, and production time are reduced [53]. Thus, the solution of visible problems becomes easier. Companies that also apply one-piece flow used takt time rather than fast production [55].According to Garlicky, one-piece flow is to ensure continuous flow at the forefront of productivity without transportation times in the production stages [56]. One-piece flow is closely related to just in time production

[49, 57]. In Lean Production, one-piece flow is to move from small batches to the whole with efficiency and continuous improvement at the forefront.

2.1.2.4 Kanban

The purpose of the company's operational excellence is to reduce stocks, operational costs, and to ensure flow [58, 59]. So, Kanban, which is one of the Lean Production techniques, is used for this purpose. Kanban, a Japanese word, is a combination of words “Kan” which means card and “Ban” which means signal. Kanban is a technique that tells what, when, and how much they will produce and where to send them during production phases [60].

In this system, cards called “Kanban” are used. Kanban cards are in the visual control tools [61]. Kanban cards contain the quantity of the parts that are placed on the parts produced in the production processes. When all parts are used, the card returns to its starting point and create new demand [62]. Kanban controls material flow during production stages, but also regulates the purchase of materials from suppliers.

Taiichi Ohno set up the Kanban system based on the supermarkets which he observed during his trip to the United States [3]. It has been successfully implemented as part of the Toyota Production System [49]. Kanban is an important Lean Production technique to control the amount of stock [49, 57]. With Kanban, visualization is made, and problems become visible through visualization. However, the purpose of Kanban is not just visualization. The main objective of Kanban is to create a system which can perform just in time production with the pull mechanism [63].

In the current process, the pull system should be used instead of the push system [64]. The most important advantage of using the pull system is the reduction of stocks [65]. Kanban systems also include activated communication, preventive maintenance and repair, and other techniques [66]. There is no need for separate stock management when Kanban is applied. Kanban ensures that excess production and waste is minimized.

2.1.2.5 Heijunka

Heijunka is the leveling of the production line following the type and the amount of production in a certain time period [21]. From top management to the bottom, everyone plan the production resources [67].

In order to respond to customer demands, production lines need to be flexible and produce quality products on a timely basis. These can be achieved with Heijunka. The bottlenecks should be identified correctly, and routing should be executed. While Heijunka eliminates large batch production to meet customer demands, it prevents wastage [14]. With Heijunka, stocks, costs, labor, and flow time are reduced [22, 68].

It is an actively applied technique in the Lean Production System, which is the most advanced version of the Toyota Production System. Toyota uses Heijunka in its hiring policy as well as using it in its production lines [69].

2.1.2.6 Value Stream Mapping (VSM)

One of the principles of Lean Production is the concept of "value" [26, 29]. Value is defined as what the customer is willing to pay for [26]. In an enterprise, analysis of all stages and representation of them with the symbols of the value stream, from the procurement process to the delivery to the customer, is called "Value Stream Mapping (VSM)" [70, 71].

Shook and Rother added value stream mapping to the Lean Production literature with their books titled "Learning to see" [72]. Thanks to them, this technique has gained a reputation. The value stream is expressed, by Rother and Shook, as a whole of the activities that create and do not create added value [72]. VSM aims to remove non-value-added operations from processes and ensures continuous flow [72].A value stream mapping application is an easy-to-implement technique [73]. What needs to be done is to monitor the production passage of the product and draw it with symbols, and then draw the future situation showing the continuous flow [70]. Solding and Gullander said that the Value Stream Mapping technique's ability to analyze the process from a wide perspective, and being easy to implement is an important advantage [73].

In the VSM, Deming's PDCA (Plan-Do-Check-Act) cycle is actively used [22, 69]. Mapping is done for the current situation and for the future situation in VSM [70]. In determining the current situation, studies such as time studies and stock monitoring are conducted to take the pre-work photograph [70, 72, and 74]. In the future situation, besides the analysis methods, Lean Production techniques are used for improvements [76, 74].

Value Stream mapping technique ensures, [27, 70, and 72].

- To visualize all processes of the enterprise

- To detect waste sources
- To solve the problem easily
- To see the whole
- To enable production processes to speak the same language.

Birgun et al. applied this in a tractor production enterprise and stated that, when the Lean Production System proposed as a result of the studies implemented, 21 days of product procurement period could be reduced to 3.5 days [24]. Abdulmalek and Rajgopal, on the other hand, reduced the time of product procurement period from 48 days to 15 days by applying the Value Stream Mapping technique in a large-scale iron and steel plant [51]. These studies and their results reveal the benefit of the value stream mapping technique.

2.1.2.7 Makigami

Makigami, which means paper roll in Japanese, is a method similar to the value stream mapping method [70]. It can be used in similar cases with Value Stream Mapping. However, the use of Makigami for the service sector is more practical [70]. Because Value Stream Mapping may lose its importance when used in the service sector [70]. Makigami, in the service sector, provides easy results in a short time [70].

In Makigami, the green sticker is used for works that create value-added, and the red sticker is used for works that create non-value-added [70]. Makigami is more visual, faster, and easier to understand than other process analysis methods.

2.1.2.8 Poka Yoke

The concept of Poka Yoke, coined in Japan for the first time in 1986 by Shigeo Shingo who worked as an engineer in Toyota, aims to eliminate mistakes caused by human, machine or design through simple, inexpensive methods [75]. The critical point in Poka Yoke is to detect and to eliminate human defect and faulty products before they happen [75, 76]. According to Shingo, in order to prevent mistakes, two types of Poka Yoke can be used [75]:

Poka Yoke as Prevention Device: This is Poka Yoke that prevents the occurrence of an error, halts the process in case of an error and prevents it from continuing. Poka Yoke as Prevention Device is to make the error occurrence impossible.

Poka Yoke as a Detection Device: This is Poka Yoke, in which visual or auditory stimuli are activated in case of an error, warns employees. Despite stimuli, mistakes can be made. It only gives information and reduces the risk of making mistakes.

Poka Yoke as prevention device is considered to be the most effective method in many cases. Poka Yoke method is an important Lean Production technique which is used for elimination and prevention of mistakes. However, because of the presence of signalizations, sensors or warning assemblies, it is seen as an expensive technique. However, successful Poka Yoke applications can be carried out with very simple visualization management and low-cost hardware [40].

In literature, many studies have been carried out on the method of Poka Yoke. Miralles et al. argue that Poka Yoke applications improve employee performance and make things easier [77]. Patil et al. define Poka Yoke as a system that resolves defects at its source [78]. Poka Yoke applications are implemented in different business branches. Grout and Tossaint conducted a study about the reduction of medical defects with Poka Yoke applications in the health sector [79]. Robinson, on the other hand, shows the application areas of Poka Yoke in the information sector [80].

2.1.2.9 Jidoka

The Jidoka concept was born when Sakichi Toyoda, the founder of the Toyota Group, invented a textile loom that would automatically stop when any thread was broken [6, 11, and 12]. Toyoda's invention made it possible for an operator to control many machines. "Jidoka" is a word created by Toyota, "Ji" refers to employees. If there is a fault condition, it must shut down the line or machine. "Do" refers to work. "Ka," on the other hand, refers to "action". Jidoka, in Toyota, is described as the combination of human and automation. Jidoka means that employees have the authority to halt the production process when abnormalities are detected [81]. In Toyota, andon, a light or audible warning system, is used to halt the line or make the abnormality apparent [69]. In Toyota, if one of the employees detects a problem, he/she halts the line. For the solution to the problem, it pulls the andon string or presses the button which informs teams. Thus, the problem is solved easily without continuing [33, 69]. If it is not solved easily, he/she receives help from support teams [33, 69].

With Jidoka, the cause of the problem is analyzed and solved in a way that it will never happen again [69]. Jidoka is based on the principle of "Revealing Problems". It should not be confused with Poka Yoke [63]. The jidoka application area is completely in the workflow. Poka Yoke is a method that is applied before the mistake happens [69].

2.1.2.10 Total Preventive Maintenance (TPM)

In 1970s a new maintenance strategy that is used in automotive technology began to arise in Japan. In 1970, J.I.P.M. (Japan Institute of Plant Maintenance) called this new maintenance strategy, aiming at improving quality and efficiency, as "Total Preventive Maintenance" (TPM) [82]. Total preventive maintenance is a technique that includes works oriented to increase the productivity or effectiveness of equipment which aims at zero failure and minimum production loss [22].

TPM aims to eliminate losses such as failure, waiting, defective manufacturing, re-processing and productivity losses that may occur in production processes [83]. The most distinctive feature that distinguishes TPM from other maintenances is the autonomous maintenance performed by employees. In order to be successful in TPM applications, employees must contribute and constantly examine all steps [84]. It has been applied in many companies and has been subject to many academic studies.

Blanchard, has assured an increase in equipment productivity and a decrease in costs by developing a method in his study on TPM [85]. Wang and Lee emphasized the importance of TPM for continuous improvement [86]. In their study Rodrigues and Hatakeyama, on the other hand, emphasize the support of top management and emphasize that TPM should be adopted by all employees [87].

2.1.2.11 SMED (Single Minute Exchange of Dies)

SMED is a Lean Production technique that was initially developed by famous Japanese Engineer, Shigeo Shingo, aiming to exchange of patterns at a single minute [88]. Shingo has studied on SMED for many years to meet the small lot and flexible production needs. According to Shingo, SMED is a feasible approach to any machine in any factory [88]. The exchange of pattern time, which is tried to be reduced to single minutes is time between the last product of the last batch and the first quality product of the new batch [89].

Shingo applies the SMED technique in 3 steps [88]. These steps are;

1. The distinction of internal preparation and external preparation

2. Transformation of internal preparations into external preparations
3. Shortening of internal preparation and external preparation separately.

Internal preparation is the activity that needs to be done by shutting down the machine and the external preparation, on the other hand, is the activity that can be carried out while the machine is running [88].

In order to simplify and standardize the setup during SMED application, tools such as method studies, value stream mapping, cause and effect analysis, Pareto analysis, spaghetti diagram, Kaizen can be used [90, 91, and 92]. The SMED technique has not only been a new technique but also a new thought system that makes an impact. Shingo has applied the SMED technique in many companies and has been successful [88]. It mainly has been used and developed by the Japanese. It is still a technique that is applied successfully [93].

Joshi and Naik implemented SMED technique with using the Pareto analysis in a company operating in the automotive industry. At the end of the implementation, it has resulted in a 30% of cost savings and 95 seconds reduction of the setup time [90]. Priyanka and Shilpa reduced setup times from 57.98 minutes to 30.1 minute with Kaizen and SMED implementations [91]. Gavali, Chavan, and Dongre reduced setup time by 18.03% in the press line with a capacity of 1000 tons by implementing 5S, Visual Management, Kaizen, Standard Operating and SMED methods [92]. Simoes and Tenera reduced the setup time by 47.5% in their study on improving the exchange of pattern time at the press line [94]. Ani and Shafei, who used the SMED technique in their studies to increase production, productivity, increased resource utilization efficiency by 95.6% by eliminating quality defects [95].

2.1.2.12 KAIZEN

Kaizen, a Japanese word, is derived from the words “Kai” which means change and “Zen” which means better [96]. Kaizen is the continuous improvement of the standard operating method by eliminating wastes [97]. The purpose of Kaizen studies is to eliminate waste in production processes. Kaizen increases quality and work safety and reduces costs as well [98]. In his book, “Lean Thinking,” Womack expressed the following words about continuous improvement: “Neither Toyota nor any company performing Lean Production is perfect. The important thing is to pursue perfection.” [26]. He emphasized that Kaizen always aims for better.

Kaizen is a process of making improvements by using small steps, and each small improvement made up of several levels [24]. Kaizen is implemented with the participation of everyone from the cleaning team to the top management [99]. Kaizen relies on making changes wherever improvements can be made [100]. Kaizen applications can usually be initiated by top management and sometimes can be initiated by the influence of external factors [69]. No matter how Kaizen applications begin, the main element is to systematize the production processes and ensure continuous improvement with participation of everyone [69].

Lean Production System is a system that respects employees' ideas, employees, and employees that contribute to the system through Kaizen applications [101]. Kaizen studies are carried out in line with the company objectives shared with employees [102]. In order to realize Kaizen studies on the reduction of costs, all employees should be cost-conscious [103]. While reducing costs in Kaizen studies, losses should be identified and eliminated primarily [104]. At this point, seven basic wastes described by Ohno come into play [3]. Kaizen is implemented to eliminate or reduce seven basic wastes [26].

Kaizen, which is also aiming to eliminate waste and just-in-time production system are two Lean Production techniques that are related to each other [105]. Kaizen philosophy says that continuous improvement should be made not only in production processes but also in social relations, in family life and business life, ultimately, in every field [106].

Imai has divided improvement into two parts as Kaizen and innovation. Kaizen is to provide significant improvement using small steps with minimum cost. Innovation, on the other hand, is the fundamental change in the current situation as a result of large investments to the new technology and tools [106]. Womack and Jones have also divided improvements into two parts as radical change (Kaikaku) and continuous improvement (Kaizen). Radical change, in other words leaping Kaizen studies are called "Kaikaku" [26].

In Imai's book, 'The Key to Japan's Competitive Success, Kaizen';

"When quality is mentioned, the first thing that comes to mind is usually the product quality. However, this is not true. Human quality comes first. A company that can engrave the quality into its employees is already halfway through its high-quality production path."

Moreover, after Imai says “engraving quality into people’s memory means helping them gain Kaizen consciousness,” and, implies that Kaizen and quality is a twin brother, and on the other hand emphasizes respect for human beings [106].

Imai, who emphasizes that employees should be trained on the use of problem-solving tools and ensured to solve the problems they have identified by using these tools, says that

“Once the problem has been solved, the achieved results should be standardized to prevent further repetition. The person, in this continuous improvement cycle, acquires Kaizen consciousness and establishes his/her discipline to achieve Kaizen in his/her work.” and adds;

“The Kaizen strategy is a constant challenge to the current standards. The standards for Kaizen are only for being changed with better standards.” [106].

According to Imai; there are similar and dissimilar techniques in Kaizen umbrella, from ‘Customer Orientation’ to ‘Commissioning of New Product’, from ‘Robot Usage’ to ‘Autonomation’, from ‘5S’ to ‘TPM’, from ‘Suggestion System’ to ‘Productivity Improvement’, from ‘Discipline at Workplace’ to ‘Employee-Management Cooperation’, from ‘QC circles’ to ‘Small Group Activities’, from ‘JIT’ to ‘Kanban’, form ‘Total Quality Control’ to ‘Zero Error’ [106]. Kaizen has contributed to the development of production systems [107]. Kaizen is vital in today's competitive conditions [108]. There are many studies in literature related to Kaizen.

Wickens explains the contribution of team spirit in Kaizen studies [109

]. Teian states that Kaizen is more than a tool. Because he stated that daily struggles are overcome with Kaizen, and it can be implemented in every field [110]. Hammer et al. emphasize that it needs process-driven thinking in Kaizen applications [111]. Deming reports that managers have adopted kaizen in continuously developing and changing competitive conditions [112,113].Vineet Kumar, in his study, states that the Kaizen philosophy should be a way of life in our working life and social life [114].

2.2 Six Sigma

In industry, seeking for differences has come into question with variable customer needs and changing competition conditions. While one consequence of these seeks is the Lean Production management system, the other is the Six Sigma management system.

The sigma (σ), a letter in the Greek alphabet, represents the standard deviation, which is the measure of variability in statistics. Sigma value is a unit of measurement in business and production processes and measures the performance of the processes [115]. Six Sigma is a method used to improve quality and productivity [116]. Six Sigma is a management philosophy which aims at customer satisfaction by basically eliminating quality defects. Six Sigma is a unique way to improve business processes through a close understanding of customer needs, and with data analysis and statistical analysis methods [117]. Defect is defined as "Anything that does not meet customer expectations." [118].

Kwak and Anbari define Six Sigma as a management system that is used to increase efficiency and productivity in order to meet customer expectations [119]. In Six Sigma, waste determination and improvement work are handled with a statistical point of view [120]. Six Sigma has many processes and steps; these steps are not the only tool in Six Sigma. These steps also include many statistical measurements.

In order to analyze the complexities and defects in the processes, the standard of Six Sigma, which refers to 3.4 errors in 1 million probabilities, has emerged [117, 121]. The criteria to be taken into consideration in the Six Sigma management system in which provides cost reduction as a result of the reduction of defects are: "Number of Defects Per Million," "Net Cost Reduction," and "Cost of Low Quality" [122].

Lurgio and Hays define the significant elements of Six Sigma, as given below [123].

- Trust and support of top management
- Focus on customer satisfaction
- Rely on numerical data instead of assumptions
- Use systematic problem-solving techniques
- Provide continuous improvement.

So, how did the story of Six Sigma begin? The story of Six Sigma began with the introduction of normal distribution curve by Carl Frederick Gauss. Six Sigma was initially developed as measurement system [124]. In the following period, in 1992, W. Shewart accepted 3 sigma deviations in the output as a limit in the process variation. He stated that when the output exceeds the limit, the production process should be intervened [125].

In the 1980s, Motorola began its Six Sigma studies to capture the high-quality level which Japan had achieved thanks to the philosophy of Lean Production that attracts attention all over the world [126]. Mikel Harry, one of the employees at Motorola, began to work on variability and deviations in the process to improve nonproductiveness caused by quality defects. Mikel Harry, established that the deviations in the processes caused customer dissatisfaction [116]. In 1986, one of the Motorola engineers, Bill Smith, began to work on a method to improve production processes and standardize error measurement for Motorola. Motorola was looking for the answer to this question: “How will we keep our success in business?” Bill Smith developed a 4-phase MAIC (Measure, Analyze, Improve, Control) cycle to reduce errors.Many improvement cycles are used in production processes. The improvement cycle formed by Bill Smith is similar to Deming’s PDCA cycle [117]. Motorola, commissioned Black and Master Black Belts, selected their statistical abilities as the baseline, and changed their management skills to work on projects with complex problems and an unidentified root cause [117].

Following Motorola, AlliedSignal Company implemented the Six Sigma management system. In 1995, many American organizations were participating this movement [126]. At the end of 1995, General Electric became one of the companies which implemented Six Sigma [127]. Under the leadership of Jack Welch, General Electric CEO, after applying Six Sigma improvement methods, at the journey that started at the sigma level of 3.4, it reached 5.7 sigma level [137]. If the Sigma level is high, the production or service process takes place with fewer errors, on the contrary, if the sigma level is low, the number of errors increases. At the end of Six Sigma applications, GE's reaching the level of 5.7 Sigma means that it reduces defects [128]. Jack Welch, who successfully implemented Six Sigma management systems, has identified Six Sigma as the essential business strategy for his companies [128]. Jack Welch and his colleagues popularized Six Sigma concept, and even Six Sigma used by the US government in counter terrorism [129].

Hahn et al. (1999), stated that employees that are applying Six Sigma into their work are carried out to higher levels professionally. [130]. Pande et al. (2003) presented a roadmap for implementing Six Sigma with step-by-step guidance and application guidelines [117]. Calcutt (2001), in his study, emphasized that how large companies such as Motorola, General Electric improve their performance positively and Six Sigma applications are part of their corporate culture [131].

By the end of the 20th century, Six Sigma has spread the whole world like wildfire [125]. Six Sigma offers companies the opportunity to achieve positive outcomes such as profitability, productivity, and market share growth. Six Sigma is not an ad-hoc fashion for a period, but it is a flexible management system that cares about customer satisfaction, pays attention to employees' training and aims to improve performance significantly [117]. After the successful implementation of Six Sigma in the production sector, Motorola implemented Six Sigma in its support processes and realized significant gains [132]. Six Sigma can also be successfully implemented in the service sector as well as in the production sector [133].

Six Sigma may initially seem costly for a company that is going to start implementing this to its management system. Before the startup phase, a cost-benefit analysis should be made. Net benefit varies from company to company. The training costs, which comprise most of the Six Sigma costs, are nearly $ 1300-30000 per person [123]. The companies that commence Six Sigma studies by sacrificing the high costs have made significant progress in product quality, product reliability, and customer satisfaction [122]. Six Sigma has helped the US production industry develop and communicate with its customers [134]. However, Brue stated that managers are hesitant for Six Sigma applications, often due to costs, which include consulting costs, training costs, and improvement costs [120,135]. Along with the companies that implement Six Sigma applications successfully, many companies that do not implement Six Sigma due to high investment costs adopt and use measurement activities at 3 sigma levels [123].

In summary, Six Sigma is a philosophy, a business strategy that implies not to work harder, but to work smarter [125, 127].

2.2.1 Six Sigma Principles

The most important objective of the Six Sigma management system is to minimize quality errors. In this system, 3 factors, including customer, process, and employee, are taken into consideration. Six Sigma principles of which focal point is customer, process, and employee are summarized in 6 titles. These are [117];

Customer orientation: Customer's expectations and needs should be satisfied. Future state estimation should be done in line with competition conditions.

Data-Driven and fact-driven method: In the Six Sigma management system, the collection of complex data and statistical analysis should be done.

Focus on process, management, and improvement: In Six Sigma, processes are places where value is created, and improvements should be done to eliminate defects.

Proactive management: Objectives should be identified and monitored in Six Sigma. Management should be ensured with goals.

Unlimited cooperation: A detailed analysis of end-user customers and business processes should be made and understood.

Orientation to perfection, tolerance for failure: Companies that implement Six Sigma management system should adopt the philosophy of continuous improvement and show tolerance for failure.

2.2.2 Six Sigma Methods

Six Sigma has two methods. These are; [119]

- DMAIC
- DFSS

The commonly used one is to Define, Measure, Analyze, Improve, and Control (DMAIC). The methods of Six Sigma are not standard, and there are different approaches [120]. Systematically, the DFSS method is to design new products and processes at Six Sigma quality levels [119].

2.2.2.1 DMAIC

In each of the DMAIC steps, process optimization is carried out by applying tools following the specific objectives. Each Six Sigma project goes through these five phases, because, after each phase, organizations are one step closer to their Sigma level target [126,136].

The main steps of the DMAIC methodology are summarized below [137].

Define: Customers' priorities and needs are defined [137]. Basic Steps are;

1. Definition of the problem by numerical data
2. Identification of the customer with problem analysis
3. Identification of the current process visually
4. Determination of specific project topics for the purpose of project scope, usage of problem-solving techniques such as problem reporting, and brainstorming.

Measure: At this phase, the Six Sigma team analyzes the current performance according to data. Basic steps are [137]:

1. Sources, causes, effects and measurement of variations and identification of its diversity
2. Identification of the required data types for the process
3. Development of data collection plan
4. Analysis of graphical measurement system
5. Data collection to find the base cause of the problem

Analyze: It is the third phase of DMAIC. It is implemented to determine the main reasons for errors. Basic steps are [137]:

1. Performing skill analysis to maintain basic competence
2. Performing selection analysis to determine which tools to be used by Six Sigma teams
3. Application of graphical analysis tools
4. Definition of variation sources using statistical tools

Improve: This phase is for designing, implementing and approving the improvements. Basic steps are [137]:

1. Production of improvement alternatives
2. Creation of a process map that includes the best improvement opportunities
3. Performing FMEA (Failure Mode and Effects Analysis) to take measures before failure
4. Performing cost-benefit analysis
5. Performing the pilot scheme
6. Comparison of sigma values before and after the improvement phase

Control: The last phase of DMAIC is the control phase. At this phase, the control method is determined and the control plan is formed. Basic steps are [137]:

1. Elimination of error probability
2. Performing analysis of long-term measurement system analysis
3. Appropriate and feasible graphs (Statistical Process Control)
4. Performing a detailed plan to control problems and measures
5. Preparation of new and revised standard operating procedures

Table 2.2.2.1.1 shows Six Sigma tools that can be used in basic steps.

Project Phase	***Candidate Six Sigma Tools***
Define	Project charter
	Voice of the customer (VOC) tools (surveys, focus groups, letters, comment cards)
	Process map
	Quality Function Deployment (QFD)
	Supplier Input Process Output Customer Chart (SIPOC)
	Benchmarking
	Project planning and management tools
	Pareto analysis
Measure	Measurement systems analysis
	Process behavior charts (SPC)
	Exploratory data analysis
	Descriptive statistics
	Data mining
	Run charts
	Pareto analysis
Analyze	Cause and effect diagrams
	Tree diagrams
	Brainstorming
	Process behavior charts (SPC)
	Process maps
	Design of experiments
	Enumerative statistics (hypothesis tests)
	Inferential statistics
	Simulation
Improve	Force field diagrams
	Failure Mode and Effects Analysis (FMEA)
	7M tools (Affinity Diagrams, Tree Diagrams, Interrelationship diagraph, Process Decision Program charts (PDPC), Matrix diagrams, Prioritization matrices, Activity Network diagram
	Project planning and management tools
	Prototype and pilot studies
	Simulations
Control	Process behavior charts (SPC)
	Failure Mode and Effects Analysis (FMEA)
	ISO 900x
	Change budgets, bit models, cost estimating models
	Reporting system

Table 2.2.2.1.1 Six Sigma tools commonly used in each phase of a project [130].

2.2.2.2 DFSS (Design for Six Sigma)

In the current state, if there are errors in the design of products or processes, DMAIC methods cannot be successful. However, DFSS may be successful in achieving improvements that meet the quality expectations in the design of products and processes

[138, 139]. If the process is new, DFSS is required. DFSS consists of various approaches for production, process, and service design. These approaches are:

- ICOV (Identify, Characterize, Optimize, and Verify) [128].
- CDOV (Concept, Design, Optimize, Verify) [140].
- DMADV (Define, Measure, Analyze, Design, Verify) [141].
- PIDOV (Plan, Identify, Design, Optimize, and Validate) [141].

The tools in the DFSS methodology are different from the DMAIC methodology. DFSS includes innovative tools such as creative problem-solving theory, axiom design, and quality function spread, but the DMAIC does not include these tools [125].

2.2.3 Six Sigma Organizational Structure

In order to implement the Six Sigma management system effectively, studies should be done convenient for the organizational structure. Six Sigma studies are managed by an organization including "generations" at various levels. The general organizational structure is shown in Figure 2.2.3.1. Moreover it is not a standard structure, there are alternative organizational structures in Six Sigma.

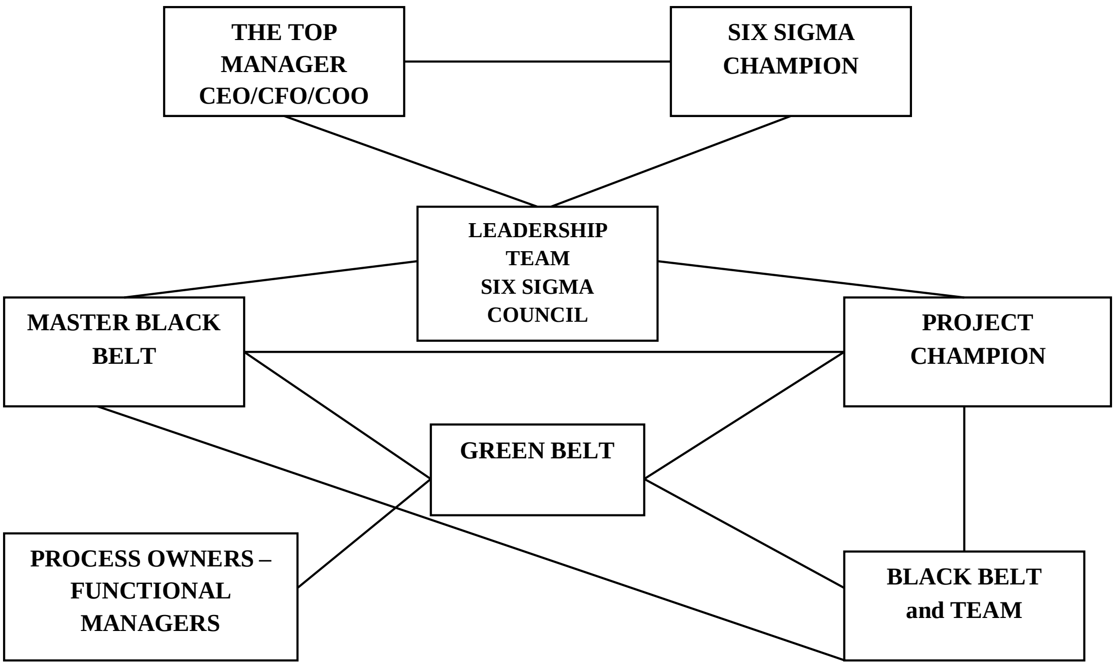


Figure 2.2.3.1 Roles of the leader [125,142]

The roles in the Six Sigma organization can be summarized herein below [143]:

Top management: The person who is the pioneer of change, and has material and moral support.

Champion: It is the person who is Six Sigma leader, and is communicator and disseminator.

Project owner: It is the person who leads the Six Sigma teams and is responsible for the success of the project.

Master black belt: It is the person who produces Six Sigma projects, implements projects, supports championship and management, and educates green belts.

Black belt: It is the person who takes part in Six Sigma projects and guides the green belts. Their training lasts for 5 months.

Green belt: It is the person who makes the change and implements the projects. Their training lasts for 7 weeks.

2.3 Lean Six Sigma

Lean Six Sigma is a management system formed by integrating the" Lean" and "Six Sigma" methods which are different concepts. It is aiming at reducing waste while providing standardization in quality [144]. Lean Six Sigma is a management system that gathers Six Sigma quality defects and reduction of processes variability under a single roof by reducing non-value-added businesses and ensuring the flow [145, 146, and 147]. George states that two methods are generally considered competitors, but he states that a merger between Lean and Six Sigma is needed because Lean does not provide statistical control to a process and Six Sigma does not radically improve the processing speed [145]. Lean Six Sigma aims to continuous improvement at the speed, cost, and quality by integrating the positive aspects of these two management systems [147].

Lean Six Sigma follows the steps of DMAIC that are the traditional Six Sigma steps. George et al. argue that the DMAIC method is an effective problem-solving technique because it contains actions such as;

- Defining the structure and scope of the problem,
- Identifying the base causes of problems,
- Finding solutions that depend on reasons following tangible data,

- Making solutions as procedures for sustainability when the project is completed [148].

The reason for the success of Lean Six Sigma is that the processes that have been improved by Lean Production methods are being made perfect with statistical methods of Six Sigma. The focus of Lean Production is to improve flow and speed of the process. The focus of Six Sigma, on the other hand, is quality rather than speed, which makes Lean Six Sigma as a powerful and successful tool for improvement is the integration of these two features [148]. Lean Six Sigma is used at Xerox, General Electric, Caterpiller, Johnson & Johnson, and Dell [149, 150]. Lean Six Sigma's four keys to success are to ensure customer satisfaction, improve processes, teamwork, and data-driven decisions [148]. Figure 2.3.1 given below illustrates the basic keys of Lean Six Sigma [148].

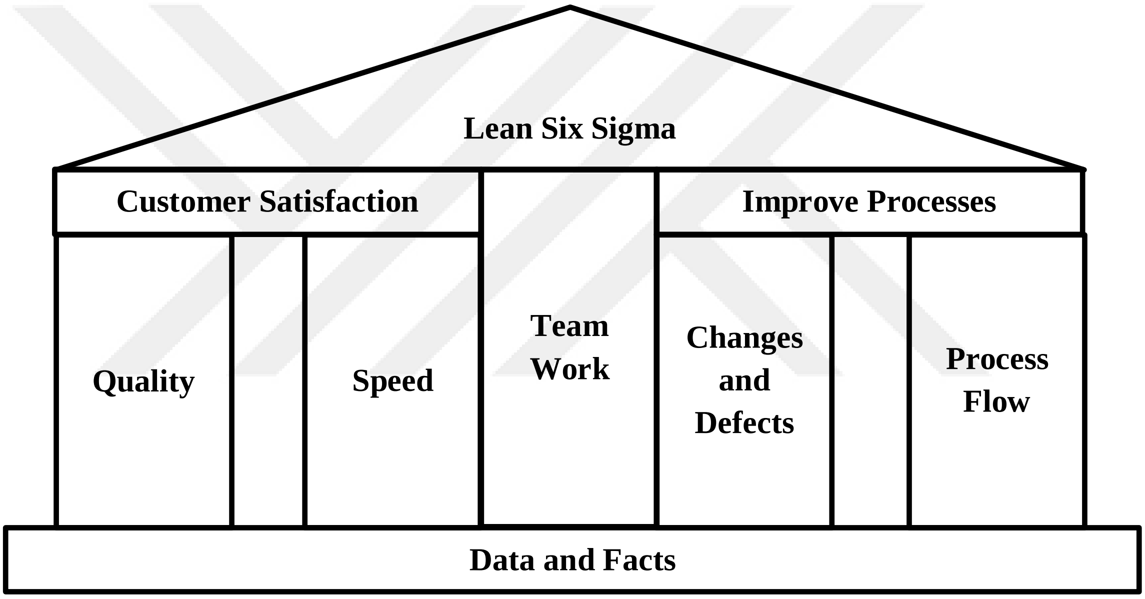


Figure 2.3.1 The basic keys of Lean Six Sigma [148]

At European Organization for Quality seminar held in Hungary in 2011, Dr. Nemeth Balazs summarizes common points and principles of Lean and Six Sigma management systems that form Lean Six Sigma system as follows [151];

- Process Thinking
- Customer Oriented
- Continuous Improvement and Problem Solving
- Fact, Data-Driven Management
- Full Participation of Company Management
- Teamwork

- Training program

The following table summarizes the differences between Lean Production and Six Sigma [147]:

	Lean	Six Sigma
Goal	Creative flow and eliminate waste	Improve process capability and eliminate variation
Application	Primarily manufacturing processes	All business processes
Approach	Teaching principles and “cookbook style” implementation based on best practice	Teaching a generic problem-solving approach relying on statistics
Project Selection	Driven by value stream map	Various approaches
Length of Projects	1 week to 3 months	2 to 6 months
Infrastructure	Mostly ad-hoc, no or little formal training	Dedicate resources, broad-based training
Training	Learning by doing	Learning by doing

Table 2.3.1 The differences between Lean Production and Six Sigma [147]

Lean Management and Six Sigma can only cover up each other's deficiencies when used together. Lean Six Sigma involves considering the similarities and the differences between two management systems and taking advantages of them effectively [147]. Companies that decide to implement Lean Six Sigma should expand their employee perfection and provide appropriate training [148]. In Lean Six Sigma applications, training on brainstorming and decision-making process are given for having team spirit [148].

The Lean Six Sigma improvement process involves the creation of a value stream mapping and the creation of Lean Production principles primarily to increase speed, and the emergence of the Six Sigma method when more complex problems occur [147,148]. The Integration of Lean Production and Six Sigma principles began in the late 1990s and spread rapidly.

The study of Sheridan (2000), one of the first examples, was carried out at the BAE Systems Controls, an aircraft engine control company, in India [127,152]. Lean Production techniques were used in the company with Six Sigma techniques in the application that began in 1997 [152]. In the BAE systems control, productivity was increased by 112% in five years, and product reliability was increased by 300% with Lean Six Sigma applications [127, 152].

One of the first Lean Six Sigma applications was made at Maytag Corporation. In 1999, they put Lean Six Sigma into practice, but the study was published in 2003 [127,153]. In the application, a new production line was designed by using Lean Six Sigma [127,153]. Maytag reduced production costs by 55%. Lean Six Sigma applications helped Maytag save millions of dollars [153].

Bossert and Walker (2002), in their studies, suggest that the Lean Six Sigma management system, which is generally implemented in the production sector, can be applied in non-manufacturing sectors such as software development, call centers, training, new product development [127, 154].

Sharma (2003), in his improvement works at a battery factory, reduced the inventory cost from $20 million to $2 million in six months by integrating lean techniques (such as pull system, Kanban, TPM, SMED, Poka Yoke, standard work documents) with Six Sigma method, increased the company's annual revenue by 17% and increased customer satisfaction [127,155]. Carnell, 2006, states that Lean Production and Six Sigma management systems cannot be used interchangeably and should be used together with consideration of human factors [156].

In his study, Chand (2011) used Lean Six Sigma to reduce the non-value-added times in health system. As a result of the studies, it was observed that non-value-added time was decreased by 64% [157]. Mandahawi et al. (2012) used a lean Six Sigma management system to evaluate the performance of cutting and printing machines in a paper production factory. It was observed that 48, 45% increase for cutting machines and 21, 6% increase for printing machines were made in equipment activities. [158]

2.4 Lean Production and Lean Six Sigma Training

The companies that are successful in the journey of change and development oppose to the resistance which is against the cultural change only with communication, motivation, teamwork, and training. In Lean Six Sigma, training is a communication tool that tells people principles and techniques of the management system. [159].

In Lean Production and Lean Six Sigma applications, teamwork is of great importance [3, 144]. While cultural change is taking place, the concept of “We” is emphasized instead of “I” In teamwork, employees can easily express their ideas in all phases and manage themselves [160]. Creating team spirit and teamwork is not as easy as it seems. Many studies should be done on this subject. Employees should be encouraged to be successful in the Lean Production and Lean Six Sigma management system by providing perfection to employees. Thus, employees can become solution producers in Kaizen applications or Six Sigma projects. If employees feel that they are valued, they do not hesitate to take responsibility for the team [160]. Teamwork aims to ensure everyone's participation in continuous improvement activities by company goals.

Companies that implement these management systems should have flexible production systems; it is also important to create flexible human resources, as well [3]. Flexible human resources can be realized by teamwork, training, and increased perfection. The difference that distinguishes Lean Production from other management systems is that the human factor takes an important place in improvement efforts. In Japanese philosophy, human beings come first [17]. In teamwork, team members express their ideas freely, support each other, make joint decisions and share the decision phase [161]. Consequently, earnings in Lean Production applications are achieved not by increased physical efforts, but by increased teamwork [162]. The key to success in management systems such as Lean Production and Lean Six Sigma is that there should be employees who are willing to implement these methods, are highly motivated, and embrace the system [14].

Employees need to motivate themselves and produce new ideas in order to adapt and support improvement efforts [69]. Morita's statement: “no matter how successful, intelligent or skillful you are, the future of your business is in the hands of people you employ.” emphasizes the importance of employees for sustainable success with a different perspective [163]. Kohei Goshi’s, one of the founders of the Japanese Productivity Center, statement, “Management requires not only technical but humanitarian qualities. We should address the people's hearts.” motives the managers to value the employees [106].

In Lean Production System, the results of the training, namely the realization of learning, are as important as training. In Lean production, learning is based on receiving the transferred information, implementing it, and transferring it to other employees [161]. In Lean Production and Lean Six Sigma management systems, the training on all subjects is provided to all employees [164,165]. In the nature of these management systems, it lies to train competent and skilled people. To sum up, if there are no competent, qualified, systematic employees, then Lean Production cannot be implemented, and if Lean Production is not available, competence cannot be provided to the employees [165]. Tom Peters expresses the contribution of Lean management system to the human approach with the following words. “In 1962, it was thought that enterprises did not offer warm and happy environments, the human approach was nonsense, and numbers set the rules. We owe gratitude to Toyota, Honda, and Sony for their contribution to the destruction of this perception.” [166].

Driskell states that the type of training, the content of training, and the experience of training equally affects the outcomes of training. Success depends on the content of training and the form of training [167]. Engetou proves that, according to the analysis of surveys conducted in his study, if the programs are designed and executed in order to define the training needs and fulfill these needs, it takes long time to improve not only the performance of employees but also the performance of the organization [168].

Training is often used to close the gap between current performance and expected performance. Gordon defines training as follows: they are the activities in which employees develop their knowledge, skills, and perfections as a result of learning behavior. That is, the gap between the current performance and the expected performance can be filled with the realization of learning [169].

In order to increase sustainability and struggle in competitive conditions, raising qualified employees has been accepted by all [170]. Therefore, more attention is paid to blue-collar employees. As a result of the change in working conditions, employees are now doing work based on the less physical labor force, more information, and teamwork. As a result of this, in order for innovation to become a culture in humans, the training needs to be maintained continuously [170].

Thanks to the provision of the right vocational training, product quality is increased, wastes are eliminated, and most importantly, job satisfaction is ensured because the employee performs his job willingly [171]. The industry needs a new generation of knowledgeable workers who are skilled in production dynamics [172].

In many studies on blue-collar training, the priority of training is also carried out by considering certain factors. These factors appear as race, gender, experience, culture, and privilege [173,174,175]. However, in all studies, experience, gender, and education background are common factors. However, in Lean Production studies, training is given to everyone without making any distinction [3, 69].

In the Lean Production and Lean Six Sigma Management system, training is offered in every field. Many studies have been conducted on these training and their outcomes. In Lean Production and Lean Six Sigma training, game-based and practice-based training are also provided besides traditional theoretical training. In Lean Production training, in order to assist industry and students, they are included in a training factory with technical simulations or a model factory with a realistic training environment.

A taught technique is sometimes understood better with a classroom activity. For example, the “Beer Game” developed by System Dynamics Group in MIT helps explaining system dynamics and the principles of supply chain behavior [176]. Rowlands (2005), in his study, states that Lean concepts can be explained through games [177].

Ozelkan and Galambosi (2007), in their study, present a new game called “Lampshade Game,” which is used to teach the concepts of Lean Production to undergraduate and graduate students. They point out that advantages and disadvantages of the Lean Production techniques are seen during the implementation phase of this game, and it is useful for teaching [178].

Friblick et al. (2007) conducted a study investigating the use of lean games and their effects in Lean Production training. They state that a lean game itself is not a process that accelerates teaching, it takes time to learn, theory and practice should be related to each other. They emphasized that Lean Games have an impact on learning; however, if they are supported by other implementations, such as simulations they increased the level of learning. [179]. Black (2008) said that the best teaching practice in Lean Production is to learn and do. He also states that training participants can convert what they see and hear into action [180]. Therefore, the principles of learning and doing are the most recommended principles in Lean Production training [181].

Ncube (2009), in his study, discusses the impacts of games and simulations on learning processes, mainly their functions as an experiential learning methodology. He states that explaining Lean Production techniques with “the Lemonade Tycoon” game has a positive impact on learning [182].

Badurdeen et al. (2010) made a critical assessment of the simulations which are used to teach Lean Production techniques. These studies are classified according to their importance by reviewing the literature. Four gaps are found in existing simulation designs: lack of stress on soft skills, a mistaken focus on “linear lean,” misunderstanding of the key role of the facilitator, and lack of realism [183]. In this study in which they evaluate the use of simulation and games to teach Lean Production techniques, they emphasize that the use of the game is effective in learning Lean Production concepts [183].

Elbadawi et al. (2010), in a study for undergraduate students, used a paper plane in a simulation game. They state that simulation game used for the explanation of Lean Production concepts increase the knowledge of students significantly [184].

Pourabdollahiana et al. (2012) have studied the method of learning that is called a “Serious Game” in production areas. The serious game is a game, used in production and engineering training that aims at learning rather than pure entertainment. In a serious game, it is stated that the participants make complex decisions apart from real practices. Furthermore, the efficiency of serious games on cognitive and affective learning outcomes in the field of production has been studied. A serious game is not a well-defined term, and in the literature, there are different terms related to this term, such as simulation games, game-based learning, and educational game [172].

Tisch et al. (2013) conducted multi-level research focusing on design and use of learning factories. Learning Factories are implementation areas that offer opportunities for practical research and training. They state that learning with learning factories can be improved continuously [185].

In a study conducted by Yukselen (2014), an educational game simulating the assembly line was designed, and its game sections were analyzed with KPIs (Key Performance Indicators). In this game in which LEGO® parts were used and participants from different sectors attended, it was determined that the lean techniques applied on the assembly line improve the line performance by the statistical analysis of the results [186].

Veza et al. (2015), in their study, examine the Lean Learning Factory in FESB (Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture in Split). Veza reported that “The Lean Learning Factory at FESB is based on a didactic concept that emphasizes experimental and problem-based learning with using tools and methods” [187]. In this study, it is stated that learning with using Lean Production tools and methods has an important role in regional development [187].

Briosoa (2015), in his study, states that Lean Production training, which is prepared by using materials such as paper, post-it, and stickers, which require low investment, is understandable. The workshop in training emphasizes the usefulness of creating simulations and discussion environment [188]. Ozelkan et al. (2016), in their study, state that simulation games used in Lean Six Sigma management system training improve student learning through active and experimental learning [189].

Blochl and Schneider (2016) examine a learning factory, which is operated by PuLL® Competence Center and performs applications and training in the field of Lean Production. With the didactic approach of simulation games, a simulation game that is integrated with Industry 4.0 has been developed for students and companies [190].

In their study, Vin et al. (2017), discuss the Karlstad Lean Factory, which is game-based and realistically simulates a factory environment. In this factory model, game-based Lean Production training is provided. They stated that, in this factory, model industrial workers learn by making mistakes and perform Lean Production techniques without giving up [191].

In their study, Veza et al. (2017), examined the development of two assembly lines designed for training and lifelong learning according to the lean learning factory concept. It is reported that these assembly lines are useful for training of students at the University of Split [192].

Messaadia et al. (2017), utilized “Muscle Car” serious game in Lean Production training. Feedbacks that were received after training showed that participants had good understanding of Lean Production by discussions between the participants and the survey results. They also refer to the positive effects of the game on the interest and motivation of the participants [193].

In their study, Leal et al. (2017), developed a game to teach Lean philosophy and analyze the impacts of the game. Learning outcomes and student motivation are taken into consideration in the design of the game. They state that all groups show a significant improvement in the assessment of learning at the end of the training and a satisfactory degree of motivation is achieved over 85% in the evaluation of motivation [194].

In their research, Aqlan, and Walter (2017) discuss the teaching of Lean Production principles to high school students and undergraduate levels. For each Lean activity, qualitative and quantitative data were collected and analyzed to evaluate the results of simulations, projects, and workshops. As a result of the analysis, they found that the simulations are effective for the understanding of Lean concepts [195].

In the study performed by Makumbe et al. (2018), Lean Production training given to the mining industry in the learning factory are examined, and they determine that the training is effective according to the survey results [196]. In their study, Yang et al. (2018), investigated the impact of integrating Lean Line Design training with industry 4.0. They indicated that the training assessment score from 20 trainees is 4.5 over 5 and that a better result is obtained than the other training [197].

Morton and Burgess evaluate the outcomes of a class exercise on Lean Production. They presented that the applied Spot Dot Company simulation game was well-received by students [198]. Darling et al. argued that learning “by doing” in a game environment is a successful method. They expressed that when using game-based learning in the understanding of engineering systems, students' motivation is increased, and knowledge sharing becomes easier [199].

In their study, Vin et al. (2018), examined the game-based Lean Production training. They stated that it is important to use the appropriate training environment for the training purpose. They stated that game-based Lean Production training is appropriate training for industrial workers [200]. In their study, González et al., analyzed the outcomes by implementing a simulation game prepared by using Lego. The outcomes were obtained through surveys conducted before and after training, and it is determined that the concepts of Lean Production are better understood at the 25% improvement rate. Analysis results show that simulation helps to learn [201].

In all these studies, Lean Production and Lean Six Sigma management system trainings were carried out by using the implementation, simulation, serious game, and game-based learning techniques apart from theoretical training. In order to teach the principles of Lean Production, a large number of lean games have been developed in the academic world and the industry. In a few of the studies, the effects of lean games on learning were analyzed with tangible data. At the same time, the number of studies comparing lean games with theoretical training is not enough.

2.5 Game-Based Learning

With the game-based learning, we come across with play, game, and gamification concepts. According to Brown the starting point of play in life begins between mother and baby, through play, interaction between the mother and the baby improves [202]. Play is an action that has no rules and purpose. Play that we encounter when we are infants is an activity that exists not only in leisure times but also in every phase of human life. According to Brown, play is a biological need like sleep and dreams [202].

Brown, one of the authors of the book titled “Play”, says that play is the next step after evolution and he describes play as a kind of magic [202]. If we don't allocate time to play, we will face a cheerless life without creativity. The opposite of play is perceived as work; however, according to Brown, the opposite of play is depression [202]. Brown says that employees who have the concept of play in their lives, and who can reflect this concept to their lives, may be more successful in their jobs compared to others [202].

Nowadays, play and game-oriented studies have attracted the attention of the business world, and play has become a required qualification for employees. As an example, Cal Tech's Jet Propulsion Laboratory (JPL) made changes to their recruitment policy. JPL is an aeronautical research facility that is fully responsible for imagining, building, and operating complex projects such as space studies and robotic vehicles which landed to Mars and examine the surface of the planet [202]. The JPL, which had been successful for many years, in the late 1990s said that they have a problem. [202]. JPL, which many employees had been retired, had difficulty in finding qualified employees to replace retired employees'. Although JPL hired people who had graduated from top engineering schools such as MIT, Stanford and Cal Tech, they found that newly hired employees were not good at problem-solving techniques which was a critical factor for their business [202]. Experienced managers observed that young engineers had difficulty in transferring a complex project from theory to practice and solving a problem [202]. This problem led JPL to look for a solution. As expected from good engineers, JPL management analyzed the problem and began to seek for solutions.

JPL added two people to its team during solution seeking process [202]. One of them is Frank Wilson, who is neurologist, the owner of the book, “The Hand”; the other is Nate Jones, a mechanical technician who specializes in precision racing and Formula 1 tires. Jones realized that many of the new employees that are working at his machinery shop could not solve specific problems, and he wondered why. After questioning new and experienced employees, Jones found out that the employees who have been working with their fingers to build things as a child and growing up could easily find and solve the problem. This finding caught the JPL management’s attention [202]. Based on this finding, JPL managers examined retired engineers and checked how they worked on a problem. JPL managers found that retired employees had been working with their fingers and hands to build things in their past. The engineers whom JPL found so ingenious were the ones who had play in their lives and constructing buildings and stereos by using their hands when they were young [202]. JPL managers decided that those young engineers who have been practicing using their hands and have been playing games are skillful in problem-solving, and these are the kind of employees that administration is looking for [202]. Young engineers who have not been practicing using their hands and did not have the concept of play in their lives are generally not good at problem-solving, even they graduated from top tier schools. From this point on, play becomes an important criterion for the hiring process, JPL starts to ask additional questions to prospective employees about their experience with the concept of play [202].

With the support of Brown and his team, a course named, "From Play to Innovation" was created at Stanford Design School. In this course, students are working on design projects with real-life partners. Throughout this course, students are given the opportunity to have different experiences with the concept of play [202].

When people learn what game adds to their lives and how, when they can connect play with their working lives, they get a sense of excitement and adventure. As a result of that, they become fully connected to the world. Play is what makes life alive [202]. According to Brown, whether we are an adult or a child, if we think of a life without play, we should know that this would be a life without humor and excitement [202]. As adults, we begin to lose the concept of play both culturally and in other respects. Adults can only prevent this loss if they give play a place in their lives [202]. Playing plenty of games in childhood makes us happy and intelligent adults; keeping it up, no matter how old we are, can make us smarter, creative, and successful [202].

Thanks to his ongoing research and interviews with 8.000 people about their play profile, Brown concluded that people who play games in their lives are usually more successful, social and happy when compared to the people that are lacking play in their lives [202]. Many studies have been done on the effects of play on the brain, which is found out that play sends a pre-warning to the brain and helps improving contextual memory [202].

While a play is an action to pass the time with no purpose and to have fun [202], the game is the action with the specific purpose whose rule is set up in advance or during the game playing [203]. Game is a complex system in which the player performs tasks bound to a series of rules [204].

According to Prensky, a game is the most exciting pastime for humanity in history. Humanity has used games to have good time and have fun [203]. For example, hieroglyphs and remains that belong to a game called "Senet" dating back to 5000 years, played with 2 people were found in Egypt [205].

Jane McGonigal, an academician and game designer, in his well-known TED speech "Gaming Can Make a Better World," and in his book "Reality is Broken" suggests that games can change the world by making us better people [206]. Furthermore, Byron

Reeves and J. Leighton Read, in their book “Total Engagement: How Games and Virtual Worlds Are Changing the Way People Work, and Businesses Compete” added that games influence not only people but also the business world [207].

Prensky, in his work, defines the characteristics of game as follows [203].

1. Games are fun.

2. Games provide intense and passionate participation.

3. Games have rules.

4. Games have goals. They increase motivation.

5. Games are interactive.

6. Games are adaptable.

7. Games have results and feedback and provide learning.

8. The sense of winning in games gives ego satisfaction.

9. In games, there is conflict / competition / challenge / opposition

10. Games provide adrenaline.

10. In games, there is problem solving which triggers creativity.

11. Games provide a place for teamwork.

12. Games have representation, story and emotional side of it.

Nothing else can provide all of this at once. Some of these features may take place in books and movies, but none of them has interactivity.

According to Prensky, the basic elements which make game a game are; [203]

1. Rules

2. Target

3. Outputs and feedback

4. Conflict / competition / struggle / opposition

5. Interaction

6. Representation or story.

When we look at the use of games in training, Gee, in his study states that games increase students’ competence on problem-solving techniques by motivating students with the way it is designed [208]. Kapp, in his study, argues that games are based on the philosophy of playing for learning rather than based on the philosophy of learning for playing [209]. In recent years, the concept of gamification, as well as the game, has become a widely accepted pedagogical approach [210,211].

The gamification, in non-gaming systems, is the use of video game components to enhance the user experience or to enable the user to connect to the environment

. These components can be listed as; participation points, badges, award, and fame systems in which leader boards are placed with levels [212]. According to Kapp, gamification is a technique used for playful thinking, bringing people together, providing motivation, and solving problems [209].

Although the concept of gamification has been on the agenda for many years as a concept, it was first voiced by Nick Pelling in 2002 [213]. However, it was mentioned in the literature for the first time when it was used by Andrzej Marczewski in 2010 [213]. The term gamification is in use since 2008, and its popularity has been increasing with the impact of conferences and players [214]. Dan Hunter and Kevin Werbach, argue that putting a surprise toy into the popcorn boxes by a company named Cracker Jack in 1912 was the first example of gamification in their book “For the Win: How Game Thinking Can Revolutionize Your Business” [215]. According to Oprescu, Jones, and Katsikitis (2014), studies aimed at understanding the use of gamification in business life are not enough yet [216].

The main purpose of gamification is to encourage the engagement of persons further and to help people create more rich experiences in daily life events while having fun [217]. Gamification aims at increasing engagement of people and supporting certain behaviors [218].

When we look at the definitions of game and gamification, it becomes clear that they are different concepts. To explain this difference by an example, it can be thought that the game is a noun, and gamification is a verb [219]. In addition to confusion between game and gamification, game-based learning is also confused with gamification in education. However, there is a significant difference between game-based learning and gamification [220]. This difference is their effects on learning. Kim, Park, and Baek (2009) stated that game-based learning enables students to achieve their educational goals by playing games [221]. Game-based learning is defined as playing games that are oriented to the learning outcomes or achievements [222]. In game-based learning, games provide pre-learning or replace learning. However, gamification occurs outside the context of the game; in other words, it does not replace learning. It focuses on overcoming a number of challenges when students are learning occasionally with tools such as badges and awards [220].

Steve Isaacs, an educator, and video designer compare gamification and game-based learning in his blog post, as in the following table [223]

Gamification	Game-Based Learning
Items inspired by the game are added to the lesson	Games which meet the targeted learning outcomes are used
In order to encourage behavior, game mechanics are added to a non-game environment	Learning occurs through game
Typically, Badges, Awards, Achievement Levels are used	It can be achieved through commercial or training-oriented games
Experience Points can be used instead of Traditional Scores	It supports critical thinking and problem-solving skills
Items inspired by the game are added to the lesson	Digital or non-digital games can be used
It can provide students with options for learning directions and methods	Simulations can be used for students to experience the subject

Table 2.5.1 Comparison of gamification and game-based learning [223]

When we look at studies on learning which differentiates gamification and game-based learning, we can see that at the beginning of 1960s NTL's Bethel and Maine campus "Practical Behavioral Sciences National Education Laboratory" and "Learning Pyramid" was formed and used [224]. According to the learning pyramid (Figure 2.5.1), one of the best ways to learn is practicing by doing [224].

In 1954, Dale presented a similar pyramid in his book, Audiovisual Methods in teaching [225]. In this study, Dale examined the learning pyramid and found that memorability of the information increases by 90% when active participation in the form of "practice-make" happens. Dale stated that effective learning takes place as a result of rich experiences such as seeing, hearing, tasting, touching, and trying [225].

In their study, Robbins and Jugge described learning as a change in behavior. Studies on learning pyramid support that changes in behavior happen when the notion of experience takes place [226].

Kolb demonstrates a different perspective on experimental learning and educational games by suggesting experimental learning theory. He described four different phases of experimental learning [227,228].

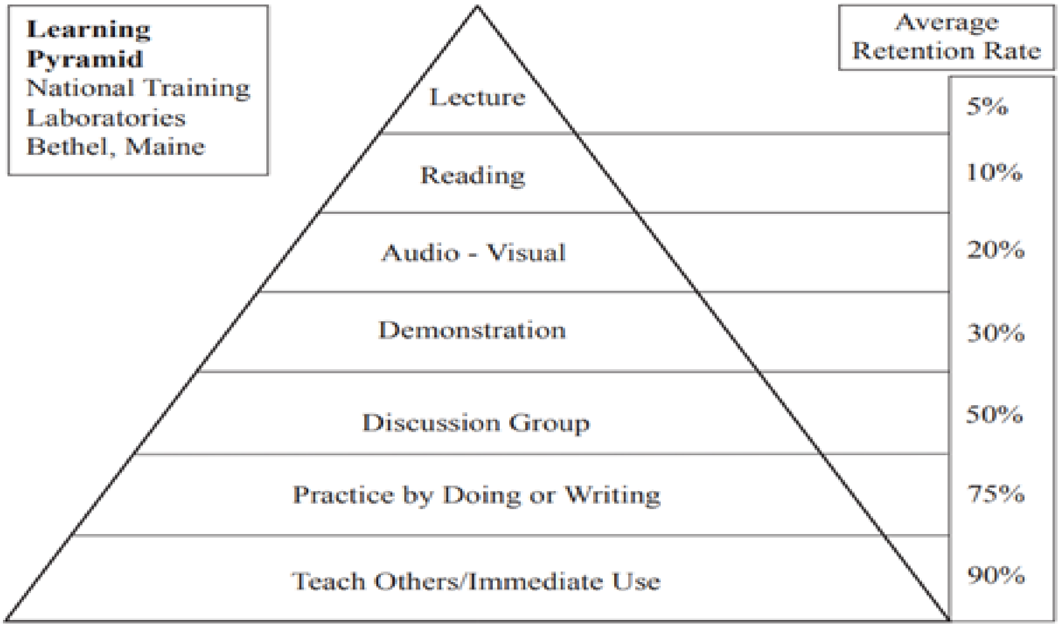


Figure 2.5.1 Learning pyramid [224]

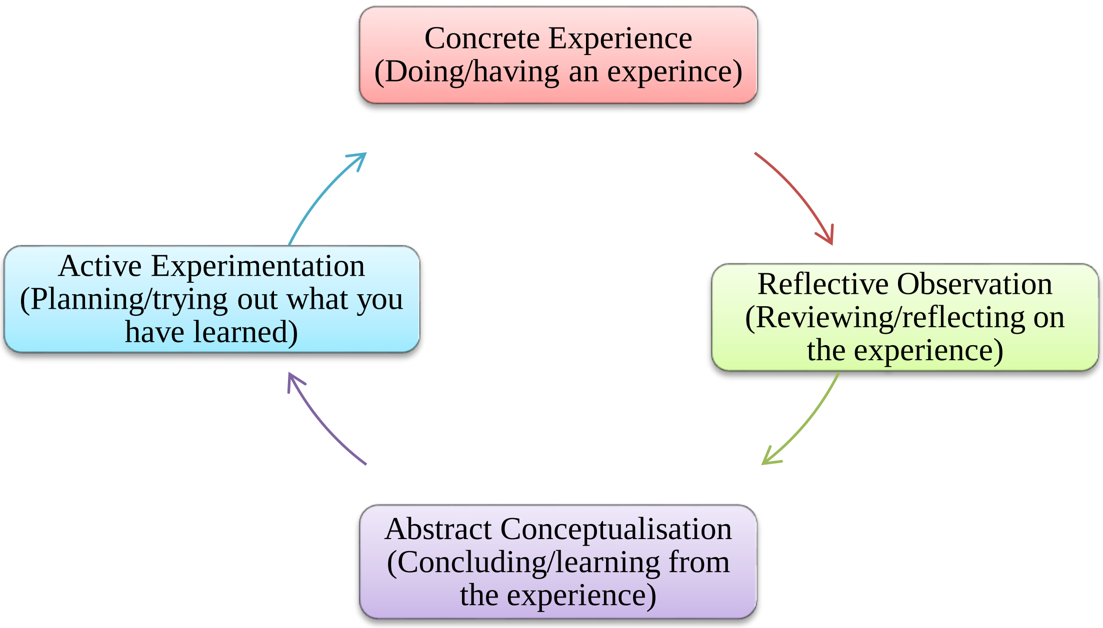


Figure 2.5.2 The experimental learning cycle of Kolb [229,230]

Keys and Wolfe investigated the use of games in training in their studies. They indicated that the use of games in training had a positive effect on learning. In addition to that, games are supporting the experimental learning cycle, which was proposed by Kolb [229]. Teamwork and feedback are also contributing to the learning process [230]. Studies show that the use of games in training accelerates the learning process and increases motivation [231]. Katrinli and Alev stated that the games used in training should be implemented in a way to support and follow up the theoretical knowledge. When the game is played after the theoretical knowledge, learners will be able to support their new experiences with old ones.

Through game-based learning (GBL), students learn by trial and error. In the experimental learning cycle, this is thought to be an effective method in learning [232].

The characteristics of GBL are given below [233, 234, 235, 236, 237, and 238].

• Motivational.

• It requires active participation.

• It provides the opportunity for interaction.

• Objectives are achieved by giving information through the story.

• Feedback is received.

• It allows a large number of students to learn at the same time.

• Provides students to learn according to their learning speed.

Game-based learning has been used in various fields such as mathematics, engineering, statistics, biology, and computer science, psychology [233, 234, 235, 236, 237, and 238]. With game-based learning, students or players develop their knowledge and skills and gain experience in problem-solving techniques [204, 239]. Game-based learning also influences success, positive attitudes, and subject achievements, student preferences, participants, and age factors [234, 237, 238, 240, and 241].

Traditional training practices often prevents creativity. Since only one correct answer is imposed on traditional training, the success rate in traditional training is low [242]. Teachers and students' cooperation in GLB environments positively affect academic achievement [243].

In his study, Adams analyzed the effect of the GBL method. He found out that GBL effects the memorability of knowledge ten times more than conventional and theoretical methods [244]. Successful GBL not only offers students a game to play but also increases the motivation and knowledge acquisition [216]. Qian and Clark also discussed the GBL in their study. When they analyzed the results of GBL studies, they found out that GBL has a positive impact on behavior and attitude at a rate of 42% and the cognitive gain at a rate of 38%. In their study, they reported that the most commonly used game type (50%) is educational game (as an example, serious games, and simulations) [245].

When considered from this point of view, it can be said that lean games aiming at facilitating the learning of Lean Production techniques, creating practical opportunities, and educational games related to Lean Production are the main arguments of game-based learning activities.

In the light of the literature review, we can say that game-based learning can be used as a method for lean games to facilitate learning of lean production techniques.

Chapter 3

Implementation of Lean Production Training and Design of the Educational Game

3.1 Training Overview of the Company

The study was carried out at a textile company's production facility in Kayseri. The company's field of activity is the production of 100% cotton jean apparel fabrics, especially denim. Production facilities of this textile company, of which corporate office is located in Istanbul, are located in Kayseri and Bahrain. The total number of employees is 2000, and the production capacity is 60 million meters per year.

With the change of competition conditions, the production facilities aim to make productions with fewer resources, increase production volume, and reduce costs. The customers have expectations of excellent products and perfect production. In order to meet these expectations, new systems and concepts have emerged each passing day. The companies that can meet the expectations mostly can survive. In order to meet these expectations, management systems were evaluated by the company, and in 2015 Lean Office was established as a result of the acceleration of improvement of works, the difficulty of execution and management, and the increase of importance of improvement works in changing competition conditions.

Lean Office is the department that conducts improvement for the company, coordinates projects for improvement, and manages the Individual Suggestion system, implement Lean Production techniques and provides training on Lean Production techniques.

So far 5S, Before/After Kaizen, Kobetsu Kaizen (Focused Improvement), Poka Yoke (mistake-proofing), One Point Lesson, TPM, SMED, FMEA studies at R&D Department has been conducted in the company. For improvement brainstorming, fishbone diagram and quality gurus in problem-solving techniques and the PDCA cycle developed by W. Edwards Deming are actively implemented. In Kaizen studies, PDCA cycles are being functioned at every phase to ensure that the studies are done have not retreated, and the improvements are sustainable. “Individual Suggestion System” has been actively implemented since 2017 in order to increase improvement in the company, support the employees, and increase employees morale and motivation.

In the company, trainings of Lean Production techniques is provided by Lean Office. In order to increase the motivation of Lean Production techniques training, which initially started as theoretical training, and to ensure easy understanding of the techniques, Lean Office added new interactive training. Lean Office classifies the trainings as theoretical and interactive training.

Theoretical training is the training in which theoretical information about Lean Production techniques is given. Training takes place in 1 to 3 hours, and number of participants is between 5 and 100. In theoretical training, handbooks with PowerPoint presentations and theoretical information are used as training materials. The theoretical training aims to use the theoretical knowledge given in the implementation phase.

Interactive training, on the other hand, is the training in which hands-on activities performed and participants actively participate, in addition to brief theoretical information that is given on Lean Production techniques. The number of people in this kind of training is between 5 and 35. The duration of the interactive training applied in the company is 1 hour on average. This training includes field applications and lean educational games.

The purpose of this training is to enable participants to learn by doing. 5S, Poka Yoke, One Point Lesson, and Problem-Solving Techniques has been given using interactive training technique in the company. As an example, theory of 5S training is given for an hour before the application of 5S training. After the theory part, a pilot region is selected in the company for the application of 5S, and the work is carried out to adapt 5S to the selected pilot region in the next hour of 5S training.

In the company, theoretical training is usually given before the applied training and lean educational games. The Marshmallow Challenge and Ball Game can be given as an example of the lean educational games that are implemented in the company. The Marshmallow Challenge is implemented to teach the PDCA (Plan-Do-Check-Act) cycle, which is actively used in Kaizen applications and is one of the problem-solving techniques. Ball Game is used for the training of Kaizen which have an essential place by the company and again to apply the PDCA cycle. Ball Game, which is used as a lean game, is adapted by the Lean Office to be used as part of the Kaizen training.

Before Ball Game, theoretical training is given as in other interactive training. Theoretical training is given for an hour in 2 weeks prior to Ball Game. In order to continue the training with the same training group, the company which has employees working in shifts, the training is given in 2-week intervals. Ball Game is implemented in 4 steps. In other words, the participants have four chances to reach the goal. In steps 1 and 2, each member of the team must touch the tennis ball with all fingers of both hands. In steps 3 and 4, this rule is modified and replaced with the two-handed touch rule to allow team members to make Kaizen. After 1st and 2nd steps are played, the new rules are announced by the moderator. The other steps are played right after the new rule is announced. Apart from that, the other rules are the same in every 4 steps.

Ball Game materials are;

- Tennis balls (one per team)
- Stopwatch for moderator
- Whiteboard or flipchart for moderator
- Timelines for recording the times of teams.

Ball Game general rules;

- The team member must throw the tennis ball in the order of the specified process. (The order of the team members, the process sequence, etc. is determined by the moderator.)
- The single round begins with the throwing of a tennis ball from process 1 to process 2 and ends up with the arrival of the tennis ball to process 4 (Figure 3.1.1).
- Teams cannot change the sequence of the process
- A team member cannot throw the tennis ball to a teammate that is standing on his/her right and left side.
- The tennis ball must be in contact with both hands of the team members.
- Teams must consist of 3 or 4 persons.
- The game must be played standing.
- Teams cannot use auxiliary materials such as a table, board, paper, etc.
- One product is formed at the end of the 8-round movement according to the sequence of the process

- The product is considered of poor quality when team members do not act by the sequence of the process as an example when the ball falls to the ground, and the ball does not touch the right hand and the left hand.

The objectives of the Ball Game are;

- Minimizing the cycle time in which the tennis ball moves with an 8-round rule
- Producing one product with high quality in 1 second at the end of the 8-round moves
- Understanding the Kaizen methodology of Lean Production Techniques
- Understanding the PDCA cycle by practicing
- Increasing the motivation of participants for Kaizen
- Increasing teamwork and team spirit
- Respecting a human being and their opinions

After the Ball Game is applied, participants' feedbacks on teamwork and improvements on their work were collected. A discussion environment created to collect the opinions of the team members. Reminders and information about Kaizen and PDCA concepts are given through examples by the moderator.

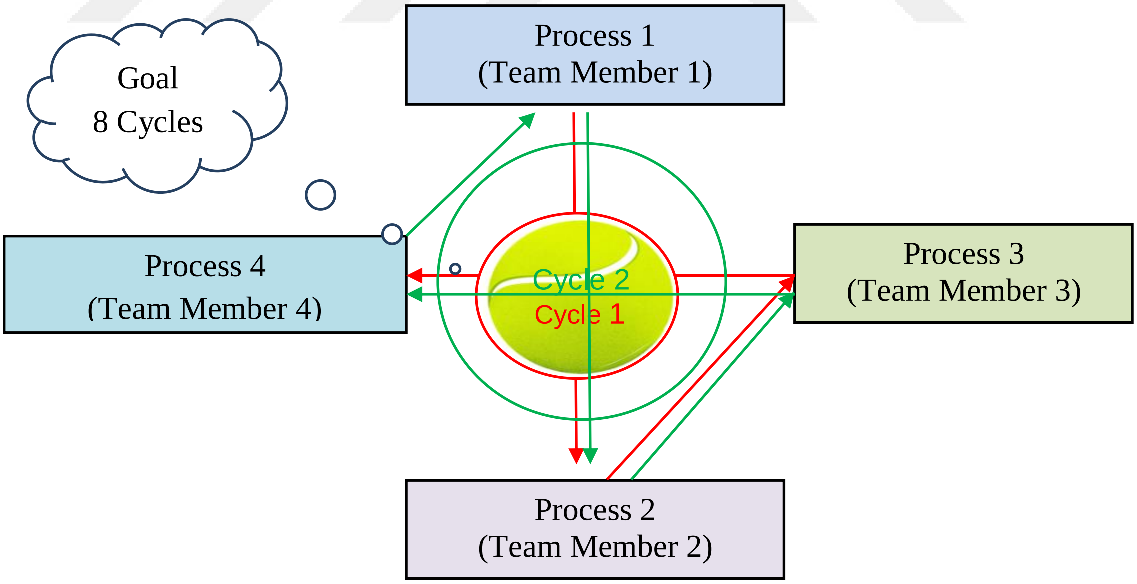


Figure 3.1.1 Example of Ball Game cycle

3.2 Design of the Educational Game

Training and outcomes of the training were analyzed in the company.

At the end of the Lean Production techniques training given, feedbacks from the participants is received verbally. At the end of the Lean Production Techniques, the end-of-training evaluation form that was created by the company used is also filled out by the participants. Limited information about the training environment, the trainer and the training are received from the participants. When the company analyzes end-of-training evaluations, it is hard to make a definite conclusion that the learning outcome is achieved. The company does not use pre-and-post test. In this respect, the knowledge level of employees cannot be measured as a result of the Lean Production techniques training.

Besides, there is no tangible data about whether performed interactive training increased motivation and learning, or lean games are effective in learning. If the pilot area has become successful for Lean Production techniques as a result of implemented training, it is accepted that the training is successful. The company also evaluates the results of interactive training by observing the performance of employees.

As a result of the conducted studies with Lean Office, advantages and disadvantages have been determined, particularly in Kaizen training performed currently. The disadvantages of the training performed currently are;

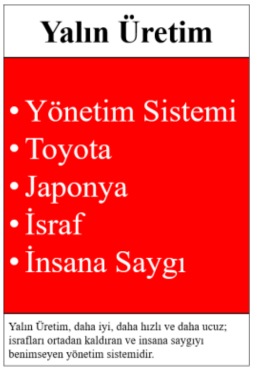
Theoretical Kaizen Training	Kaizen Training with Ball Game
• Excessive theoretical knowledge • Insufficient education materials • Lack of teamwork • Non-use of improvement forms • Boring • Excessive training time for participants • Lack of practicing • The excessive number of participants • Lack of interaction • Lack of communication	• Failure to learn concepts • Not able to establish a link between theoretical knowledge and practice • Participants focus on duration • Insufficient training period • Confusing the concepts • Non-use of the PDCA cycle form • Non-use of Before-After Kaizen form • Failure to make changes during the game process

Table 3.2.1 Training comparison

Results from the brainstorming of the Lean Office were analyzed, and the fishbone diagram was created. A cause and effect diagram, often called "fishbone" diagram. It helped to identify possible causes of faults in training and sort ideas into useful categories. Fish Bone Diagram is given in Figure 3.2.1. Since there is not training that can eliminate the reasons in the fishbone diagram, it was decided to design training that will eliminate the causes of the problem. In order to overcome the faults in training, new lean game has been designed.

The designed lean game was named "Kaizen Word Game". The purposes of the game are,

- To ensure participants learn Lean Production concepts
- To increase memorability of Lean Production techniques
- To ensure an understanding of connections between concepts
- To ensure the use of Kaizen and PDCA forms which is not used in other training.
- To increase employees' motivation
- To increase communication among employees
- To create team spirit
- To ensure participants to learn the Kaizen and PDCA cycle by hands on experience.

<table>
<tr>
<td>
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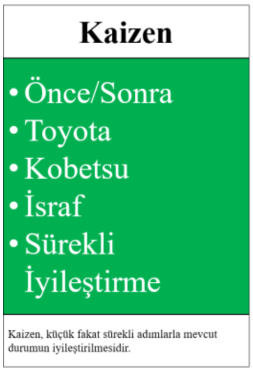
<td>
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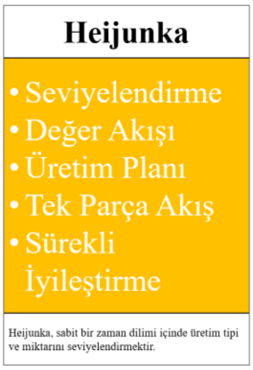
<td>
</td>
</tr>
<tr>
<td>Red Card: Its difficulty level is 1 with the concepts related to Lean Production techniques. Red Cards are the easiest cards.</td>
<td>Green Card: Its difficulty level is 2 with the concepts related to Kaizen and Problem Solving Techniques.</td>
<td>Orange Card: Its difficulty level is 3 with the concepts related to Lean Production Techniques.</td>
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Table 3.2.2 Kaizen Word Game cards

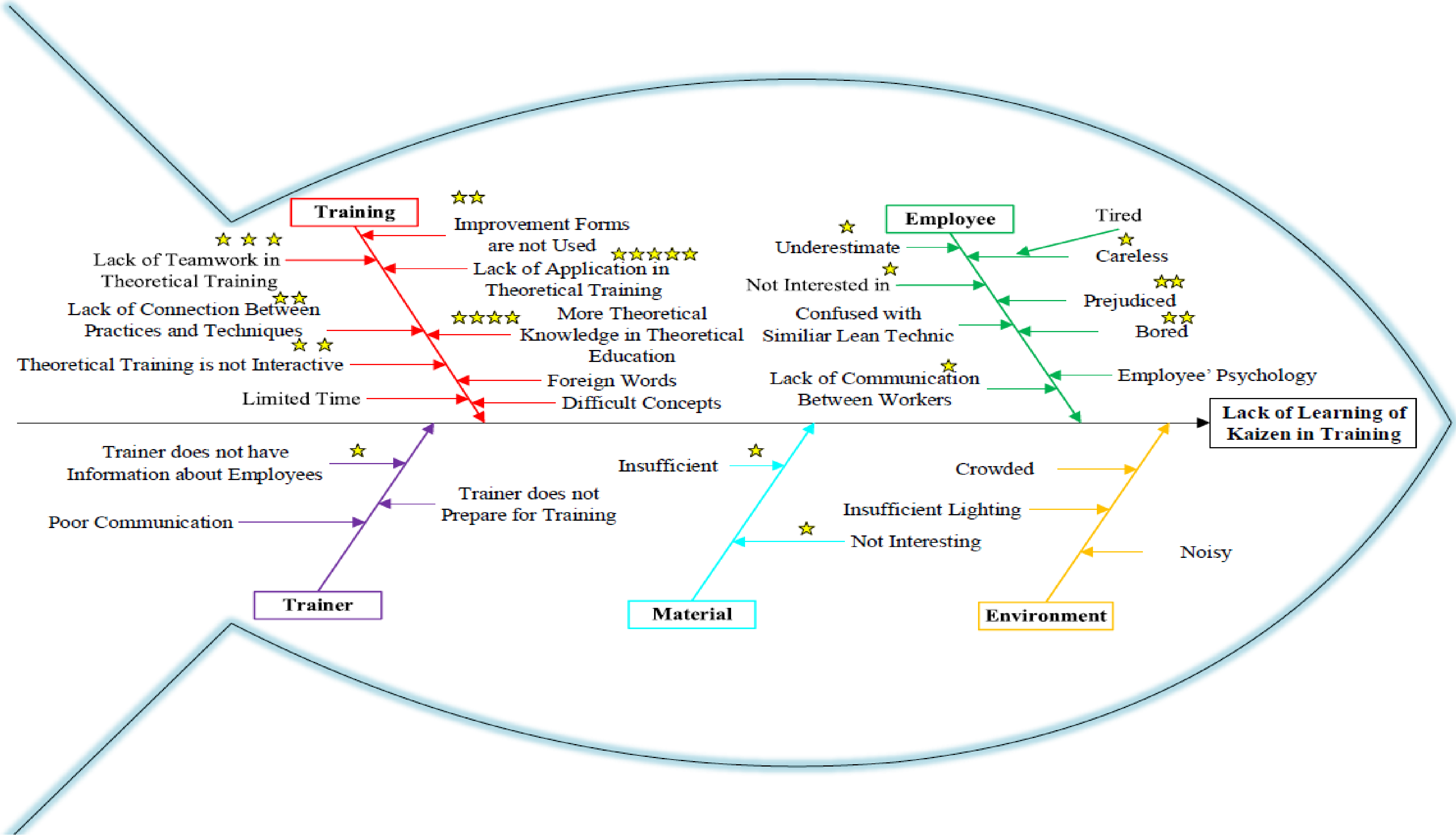


Figure 3.2.1 Fish Bone Diagram

The word that the participant will explain to his/her teammates is placed at the top of the card. The participant must explain the word at the top without saying the banned words in the middle of the card. The definitions of Lean Production Concepts are given at the lower part of the cards to facilitate participant's learning the Lean Production concepts. Three kinds of cards are designed for Kaizen Word Game in Table 3.2.2.

Materials used in the game;

1. Kaizen Word Game cards
2. Whiteboard or flipchart
3. Data collection form (Appendix 1)
4. PDCA cycle form (Appendix 2)
5. Before-After Kaizen form (Appendix 3)
6. Stopwatch

In the Kaizen Word Game, the phase of explaining the cards is linked to the production phase. Each team member represents a production process. A product is formed when a team member's explaining 4 of the cards in compliance with rules, and if other team members guess them correctly. Customer demand is to explain 12 cards or 3 products. Kaizen Word Game is designed to be implemented in 60 minutes, because the company devotes 60 minutes to each training on the Lean Production techniques. The game was originally designed as 4 sections. In section 1, the game is played without giving Lean Production Techniques. At the end of section 1, a 10-minute training period with brief theoretical knowledge on Lean Production techniques is carried out. In section 2, section 3 and section 4, on the other hand, participants are expected to perform improvement works using Lean Production techniques. However, at the pilot schemes, because required time for the implementation for Section 4 was not sufficient and the outputs of Section 4 were the same as the Section 3 ones, Section 4 was removed from the game. In Kaizen Word Game, the goal is defined to participants as explaining the cards and knowing them in accordance with customer demand. Thus, participants are given the opportunity to practice the PDCA cycle and Kaizen while learning the concepts of Lean Production.

The rules of Kaizen Word Game;

- The word on Kaizen Word Game card must be explained without saying the banned (taboo) words.

- Teams must consist of 3 or 4 persons.
- One product is achieved as a result of 4 cards being explained and guessed right.
- The goal is to guess 12 cards right, and to achieve 3 products, by the team members.
- The team members must explain the cards according to order of production process.
- The right to say pass is unlimited.
- When saying pass, the turn is passed to the other team member.
- One team member can explain one card only when it is his/her turn.
- Cards are given randomly.
- When one orange card is explained, 30 seconds are saved from total time (because it is difficulty level is 3).
- The orange card could not be explained after demand of the customer (12 cards) is completed.
- The team that explains 12 cards in the shortest time wins the game.

The content of Kaizen Word Game;

1. Descriptions of the game
2. Implementation of Section 1
3. Training for informing
4. Discussion of the results and recommendations
5. Implementation of Section 2
6. Having team meetings
7. Implementation of Section 3
8. Discussion of the results, question, and answer

The sections of Kaizen Word Game;

Section 1: Section 1 is implemented without giving information on Lean Production techniques and Kaizen training. In section 1, the goal is to guess correctly 6 red and 6 green cards. Explanation of orange cards are left to the decision of the team members. In Section 1, a total of 12 cards, that means 3 quality products must be achieved. All the team members play the game during the scheduled process by the facilitator. At the end of Section 1, theoretical information on Lean Production techniques and Kaizen concepts are given. (Duration: 10 min.)

Section 2: Before beginning the game, the session for a meeting is scheduled for the PDCA cycle and Kaizen applications. At the beginning PDCA cycle forms and pre-post Kaizen forms that will be used in Kaizen applications are given to the teams. The goal is to guess correctly 6 Red and 6 Green cards. The customer request is 12 cards that means 3 quality products and is the same as the demand in Section 1. All team members play the game during the scheduled process by the facilitator. During the game, the facilitator provides information to reinforce the concepts of Lean Production. In this section, the use of Lean Production concepts to reduce the completion time is expected. Orange cards are expected to be used for Kaizen.

Section 3: Before beginning the game, the meeting session is scheduled for the teams the goal of the teams in Section 3 is to guess correctly 4 Red and 8 Green cards as soon as possible. In this section, the customer demands 12 cards, but this time the type of the card is changed. In order to learn the concepts of Kaizen and problem-solving techniques, the number of green cards is increased. In Section 3, the teams are able to play the game during the process determined by them. In order to complete it, the team members are expected to perform new Kaizen and PDCA Cycle as soon as possible.

The facilitator collects the PDCA cycle and the Before-After Kaizen forms at the end of the training. At the beginning of the game, it is checked whether the actions taken for PDCA cycle phases are successful with team members. PDCA Cycle example is given in Figure 3.2.2.

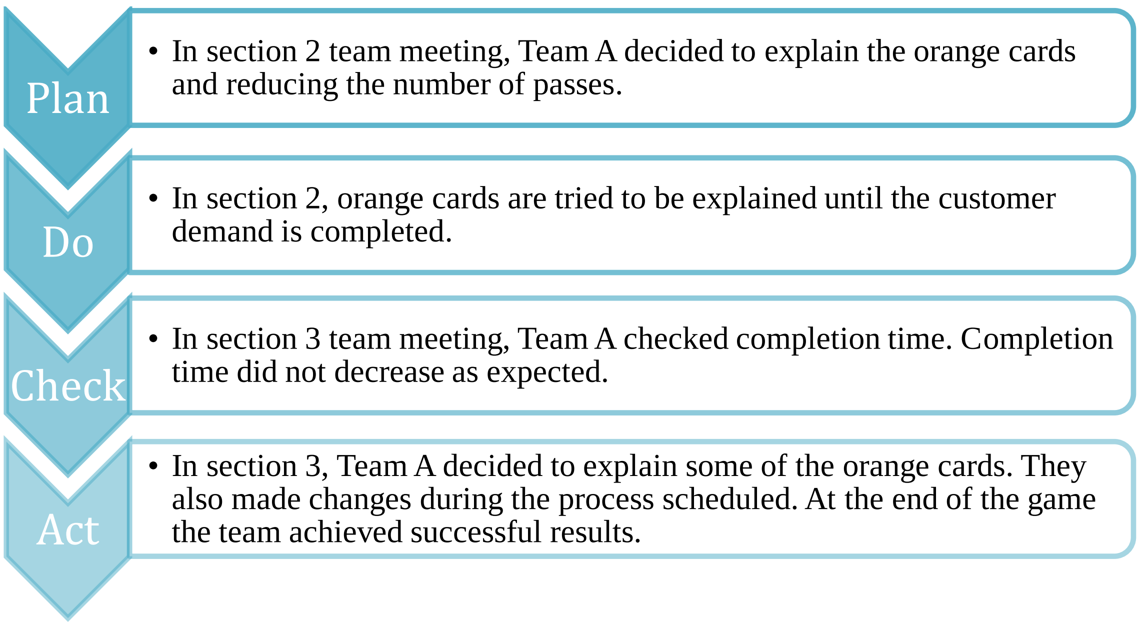


Figure 3.2.2 PDCA cycle example

At the end of the training the facilitator share her/his comments about the team members' performances. The results are discussed with the team members. The team that finishes it in the shortest time is specified, and their accomplishment celebrated with other teams.

3.3 Implementation of Lean Production Training

3.3.1 Methodology

The aim of this thesis is to help firms make the right decisions in the selection of the trainings and analyze the effects of new designed lean game which is actively used in Lean Production and Lean Six Sigma management system trainings.

The study focused on the following research questions:

1. How do the choice of Lean Production and Lean Six Sigma training affect learning?

a) How do the standard training in Lean Production and Lean Six Sigma affect learning?

b) How do lean games in Lean Production and Lean Six Sigma training affect learning?

c) How does new designed interactive Lean Game in Lean Production and Lean Six Sigma training affect learning?

2. How do the key performance indicators of new designed interactive Lean Game change?

In this study, answers for the research questions will be sought. The company where study is carried out has not been evaluating the outcomes of their trainings. Also, achievement tests are not carried out for Lean Production trainings. On the other hand, there are collecting data at the end of the trainings, however, they provide limited results regarding the training outcomes and learning objectives. To gather information about the outcomes of the training, participant views collected through evaluation surveys, open ended questionnaires and achievement tests which are applied at the beginning and at the end of the trainings were used [246].

In the 1960s, Stake conducted studies on evaluation. He emphasized the differences between regular and irregular evaluation. He has carried out his studies and aimed at the dissemination of regular evaluation [247]. Irregular evaluation is not based on tangible data and is conducted with ordinary observations, intuitive and subjective judgments [247]. In the company where the study is carried out, irregular evaluation is conducted currently with evaluation forms and observations. Regular evaluation, on the other hand, is based on structured observations, checklists, questionnaires, evaluation forms, and standardized achievement tests [247]. When the irregular evaluation is carried out at a training, it is emphasized that commenting on the impact and effectiveness of the training may be misleading [248].

In addition to observation, achievement test is prepared to be implemented before and after the Kaizen training in order to implement a regular evaluation. Theoretical and interactive training documents used to compile the achievement test. First five questions of the 10-question achievement test are related to the general structure of Lean Production Techniques. Other 5 questions of the achievement test are related to the Kaizen technique. The questions of achievement tests include the concepts that are asked to be given to participants in Kaizen training. Employees receiving Kaizen Training are expected to respond correctly to all questions of a 10-question achievement test. The achievement test has been applied before and after the training. An achievement test (Pre-Test) is given in Appendix 4.

At the end of the training, training evaluation is added to the achievement test (Post-Test) to make a regular evaluation. In the training evaluation, the employees are asked to evaluate their end-of-training achievement within the range of 5 to 1 points. Point 1 means “Very unsatisfied,” and point 5 means “Very satisfied.” Employees can also evaluate the training generally in the range of 5 to 1. The control of whether the main outputs of the training are transferred to the employees can be checked by taking the outcomes of the end-of-training with the evaluation form. The opinions of the employees about the training are taken with the part of your opinions and suggestions in training evaluation. In the Lean Production management system, which is a friend of respect to people, receiving and implementing the ideas of the employees is an important element for the improvement works to become a company culture. In order to avoid the contradiction between the improvement (Kaizen) training given to employees and the concept which is desired to be given, the ideas of the employees should be valued and improvements should be made by the ideas of the employees. In the achievement test (Post-Test) performed at the end of the training, employees are expected to respond correctly to all questions of a 10-question achievement test. The evaluation form is given in Appendix 5.

Training groups are formed in the company where the study is carried out. While forming training groups, employees, who do not receive Kaizen training and similar training, are preferred. Currently, the company gives Theoretical Kaizen Training before implementing Ball Game which is interactive Kaizen training. However, it is not able to measure the effectiveness of this training on learning. The effect of Kaizen training on learning will be analyzed with the achievement tests and training evaluations. The first training group and the order of the training given are prepared by taking into consideration the order of training currently used by the company. Theoretical training, the Ball Game and the newly designed Kaizen Word Game were given to 35 blue-collar employees in the 1st training group at 2-week intervals. Achievement tests and training evaluations were performed at the beginning and end of this training. In this training group, the effects of Theoretical Kaizen Training on learning and the effects of lean games, performed after Theoretical Kaizen Training, on learning were analyzed.

Training content and implementation order of 1st training group are;

1. Theoretical Kaizen Training
2. Ball Game
3. Kaizen Word Game.

In order to analyze whether the training orders of the 1st training group, which began with the theoretical training, affect the learning, 3 trainings were given to 16 blue-collar employees in a 2nd training group with 2-week interval by creating the reverse cycle. In this training group, the effects of Kaizen Word Game, which would be applied for the first time to the employees who had not previously received Kaizen training, on learning and key performance indicators were analyzed. If the company implements 3 trainings in Kaizen training, the company can easily decide on whether it will begin with theoretical training or with lean game after the analysis of the effects of 1st and 2nd training groups on learning. Thus, the intuitively chosen training and training evaluation will not be misleading.

Training content and implementation order of 2nd training group are;

1. Kaizen Word Game
2. Ball Game
3. Theoretical Kaizen Training.

3rd Training Group was formed considering the possibility of improvement on the number of training or the duration of training when the company, which conducted the Lean Production management system that aims to eliminate wastes, knows the effects of training and implementation order on learning. 34 blue-collar employees, who were from the 3rd training group and had not previously received Kaizen training, were given only Theoretical Kaizen Training. Training achievement tests and training evaluations were conducted. Here, it was aimed to analyze the effects of theoretical Kaizen education on learning and compare it with the work groups who had received 3 trainings.

Training content of 3rd Training group is;

1. Theoretical Kaizen Training

4th Training group was formed to analyze the effects of Kaizen Word Game on learning, to analyze game KPIs, and to compare with other training groups. In the 4th Training Group, 34 blue-collar employees had not previously received Kaizen training.

Training content of the 4th Training group is;

1. Kaizen Word Game.

3.3.2 The Key Performance Indicators of Kaizen Word Game

Some Key Performance Indicators (KPIs) are needed to see the effect of Kaizen Word Game, which is designed to overcome the Kaizen training deficiencies which were determined as a result of training analysis in the company.

In the 1st section, of the game implemented without Lean Production techniques training. The outputs of the team members' collaboration indicate the individual performances of the team members. Section 2 and Section 3, on the other hand, provide information about the effectiveness of the game.

The outputs of Kaizen Word Game were recorded with data collection form, which is one of the materials used in the game. There are 3 outputs of the game and KPIs' to evaluate performances. Game outputs are cycle time (the time of 4 cards), completion time (delivery time of 12 cards, 3 products) and the number of quality errors. The number of quality errors are the total number of passes and errors in Kaizen Word Game. KPIs are calculated from game outputs which are coefficient of variation of cycle times, rate of improvement at completion time and number of quality errors.

The outputs of Kaizen Word Game are;

Cycle time: Cycle time is described as how often a part or a product is completed by the process time as timed by facilitator [21,186]. Cycle time indicates the importance of production rate and standard business efficiency in Lean Production. Therefore, it is one of the critical output of the Kaizen Word Game.

Completion time: According to Lean Production, what the customer takes the risk to pay money is 'value'. For customer satisfaction, the value should reach to the customer as soon as possible [26, 186]. Therefore, the completion time is a critical performance.

Quality errors: The producer must produce the product requested by the customer at once [6, 234]. The quality element, which is an important criterion in Lean Production techniques, is checked and recorded during the game.

KPIs are used not only for performance evaluation but also for measuring the effectiveness of the game [186]. KPIs of Kaizen Word Game are;

Coefficient of variation of cycle times: The coefficient of variation of cycle times demonstrates the determination of participants in the understanding of Lean Production techniques [186].

Net completion time: The net completion times are the completion times of 12 cards. The completion times of all teams have been taken for 3 sections of the game. The goal is that each team's completion time is on a decreasing slope.

The number of quality errors: The quality error in the Kaizen Word Game is to misread, mislead, or pass a card. The number of errors is the sum of the number of Pass and Error.

Kaizen Word Game, designed by Burcu Kurt Özden with a game-based learning technique, was implemented to 85 blue-collar employees at the specified company as Kaizen training. For KPI analyze, the data that was collected from the group of 50 blue-collar employees who had not previously received Kaizen training in group 2 and group 4 were used. Achievement tests and training evaluations of the training were conducted at the beginning and the end of the Kaizen Word Game Training.

Chapter 4

Implementation of Training and Evaluation of Results

4.1 Implementation of Training

In the content of the study, 119 employees are given Theoretical Kaizen Training, Ball Game and Kaizen Word Game about Kaizen technique which is one of the Lean Production Techniques in four different training group. This study was conducted with 118 male employees and 1 female employee. The table of training groups is given in Table 4.1.1.

	Group 1	**Group 2**	**Group 3**	**Group 4**
Number of People	35	16	34	34
Number of Training	3	3	1	1
Training	Theoretical Kaizen Training	Kaizen Word Game	Theoretical Kaizen Training	Kaizen Word Game
	Ball Game	Ball Game		
	Kaizen Word Game	Theoretical Kaizen Training		

Table 4.1.1 Training group

4.1.1 Demographic Structure of the Training

In this chapter, the findings of the demographic structure of the groups and the results of the analysis for the purposes of the research will be given. Also, analysis of the employees' age, level of education, and experience will be given.

In the first group, a total of 35 employees were given three trainings with Theoretical Kaizen Training, Ball Game, and Kaizen Word Game. In the second group, total of 16 employees were given three trainings respectively Kaizen World Game, Ball Game, and Theoretical Kaizen Training. In the third group, a total of 34 employees were given only Theoretical Kaizen Training. In the fourth training, a total of 34 employees were given only Kaizen World Game.

The ages of employees that were participated in the given training, were grouped as 20-30, 30-40, and 40-50. The distribution of the age groups of the participants according to the training groups are given in Table 4.1.1.1. When the ages of the participant groups were analyzed, it was observed that the general participant profile was usually in the 30-40 age group.

Age Group	G1	G2	G3	G4
20-30	17,1%	12,5%	11,8%	14,7%
30-40	77,1%	62,5%	67,6%	70,6%
40-50	5,7%	25,0%	20,6%	14,7%

Table 4.1.1.1 Age distribution

Employees who have received training, work experienced ones were grouped as 0-5, 5-10, 10-15, 15-20 and 20-25 years. The distribution of the experience of the participants are given in Table 4.1.1.2. When the experiences of the participant were analyzed, it was observed that the employees who received the training usually have 5-10 years of work experience.

Experience Group	G1	G2	G3	G4
0-5	22,9%	62,5%	20,6%	38,2%
5-10	74,3%	25,0%	44,1%	29,4%
10-15	2,9%	6,3%	8,8%	14,7%
15-20			17,6%	8,8%
20-25		6,3%	8,8%	8,8%

Table 4.1.1.2 Experience distribution

The distribution of the education level of the participants according to the groups are given in Table 4.1.1.3. When the graduation level of the participant was analyzed, it was observed that the employees who received the training are generally high school graduates.

Graduation	G1	G2	G3	G4
Primary School	5,7%	6,3%	2,9%	2,9%
Secondary School	10,5%	43,8%	5,9%	17,6%
High School	75,2%	37,5%	79,4%	67,6%
Associate Degree	8,6%	12,5%	11,8%	11,8%

Table 4.1.1.3 Graduation distribution

4.1.2 The Results of Achievement Test

In this study, the achievement test was implemented in order to analyze the effects of the training on learning. First five questions of the 10-question achievement test are prepared in terms of the general structure of Lean Production Techniques. Other 5 questions of the achievement test are from the Kaizen technique. Questions of achievement tests include the concepts that are given to participants in Kaizen training. Employees receiving Kaizen Training are expected to answer correctly to all questions of the achievement test (10 questions). The achievement test has been implemented before and after the training.

Pre-post achievement tests were analyzed statistically. Each participant's answers were uploaded to the SPSS program. 2210 data including 221 rows and 10 columns were analyzed. The example of data set is included in Appendix 6. In this study, descriptive statistics (percentage and frequency), Paired Samples T-Test, Independent Samples T-Test, Analysis of Covariance (ANCOVA), Multiple Regression Analysis were used.

The purpose of the paired samples test is to determine whether there is statistically evidence that the mean difference between paired observations on a particular outcome is significantly different from zero. The paired sample t-test has four main assumptions:

- The dependent variable must be continuous (interval/ratio).
- The observations are independent of one another.
- The dependent variable should be approximately normally distributed.
- The dependent variable should not contain any outliers.

The assumptions were checked and for the paired samples t-test were met. Paired Samples T-Test was use to analyze that pre-and-post tests' results. Also, paired samples t-test was used to determine if there is a significant difference between the means for trainings implemented in group 1 and group 2. The correct numbers of the training groups with different individuals were analyzed by Independent Samples T-Test. Normality, homogeneity of variance and random independent samples of assumptions are required for independent t-test. In addition, independent t- test requires the following additional assumptions:

- Dependent variable that is continuous (i.e., interval or ratio level),
- Independent variable that is categorical (i.e., two or more groups),
- Cases that have values on both the dependent and independent variables,
- Independent samples/groups (i.e., independence of observations).

The assumptions were checked and were met for independent samples t-test .Independent samples t-test can be used to determine whether there is a statistically significant difference between the means of two independent samples.

Analysis of covariance (ANCOVA) was used to analyze if there was any significant difference between groups according to pre-and-post test results. Normality, homogeneity of variance and random independent samples of assumptions are required for ANCOVA. In addition, ANCOVA requires the following additional assumptions:

- For each independent variable, the relationship between the dependent variable (y) and the covariate (x) is linear,
- The lines expressing these linear relationships are all parallel (homogeneity of regression slopes),
- The covariate is independent of the treatment effects (i.e. the covariant and independent variables are independent.

All assumptions were checked and were met. In ANCOVA, it is analyzed that training groups that are independent variables' effect post-test correct answers that are dependent variables, it is also analyzed that effects of another dependent variable which is pre-test correct number (covariate) affects dependent variable.

Multiple regression analysis is done to analyze the relation between post-test correct number and age, experience and graduation status. Multiple linear regression analysis makes several key assumptions:

- Linear Relationship,
- Multivariate Normality,
- No Multicollinearity,
- Homoscedasticity.

The assumptions were checked and were met. Hypothesis tests are formed in the analysis.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of the Theoretical Kaizen Training implemented in group 1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of the Theoretical Kaizen Training implemented in group 1.*

Table 4.1.2.1 includes the paired samples t-test for the correct answers of pre-post test of the Theoretical Kaizen Training implemented to the training group 1. According to the results of the t-test, there is no statistically significant difference between the pre and post-test of the Theoretical Kaizen Training implemented in the 1st group (t: -1,172; p> 0, 05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 1		N	Mean	SD	t	p
Theoretical Kaizen Training	Pre-test	35	7,23	1,767	-1,172	0,249
	Post-test	35	7,57	1,632		

Table 4.1.2.1 T-test for pre-and post-test of Theoretical Kaizen Training in group 1

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of the Ball Game implemented in group 1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of the Ball Game implemented in group 1.*

Table 4.1.2.2 includes the paired samples t-test for the correct answers of pre-and-post test of the Ball Game which is implemented in the training of group 1 as the second training. According to the results of the t-test, there is significant difference between the correct answers of pre-and-post test of the Ball Game (t: -2,347; p <0,05). The hypothesis H0 is rejected and the hypothesis H1 is accepted.

Group 1		N	Mean	SD	t	p
Ball Game	Pre-test	35	7,71	1,840	-2,347	0,025
	Post-test	35	8,29	1,226		

Table 4.1.2.2 T-Test for pre-and-post test of Ball Game in group 1

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of the Kaizen Word Game implemented in group 1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of the Kaizen Word Game implemented in group 1.*

Table 4.1.2.3 includes the paired samples t-test for the correct answers of pre-and-post test of Kaizen Word Game in the training group 1 as the last training. According to the results of the t-test, there is statistically significant difference between the correct answers of pre-and-post test of Kaizen Word Game (t: -4,552; p<0,05). The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 1		N	Mean	SD	t	p
Kaizen Word Game	Pre-test	35	8,80	1,256	-4,552	0,000
	Post-test	35	9,57	,884		

Table 4.1.2.3 T-Test for pre-and-post test of Kaizen Word Game in group 1

After Kaizen Word Game implemented into the training, it was observed that the mean of correct answers obtained by the participants increased significantly. When this increase analyzed, it was found that Kaizen Word Game which was performed as a third training has the highest increase rate. It is also seen that there is no fading between the training carried out in connections with each other in the first training group.

With the data of post-test correct answers to the training implemented in the first training group, the analysis was made among themselves. Theoretical Kaizen, the Ball Game and Kaizen Word Game were analyzed in pairs.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests.*

Paired samples t-test conducted between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests are shown in Table 4.1.2.4. According to the results of the t-test, there is a statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests (t:-1,205; p<0,05).The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 1	N	Mean	SD	t	p
Theoretical Kaizen Training	35	7,57	1,632	-1,205	0,008
Ball Game	35	8,29	1,226		

Table 4.1.2.4 T-test between the data of Theoretical Kaizen Training and Ball Game post-tests

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of Ball Game and Kaizen Word Game post-tests.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the number of correct answers of Ball Game and Kaizen Word Game post-tests.*

In Table 4.1.2.5, t-test carried out between the correct answers of post-tests of Ball Game and Kaizen Word Game performed in the 1st group were given. According to the results of the t-test, there is a statistically significant difference between the number of correct answers of Ball Game and Kaizen Word Game post-tests in the 1st group (t: -5,767; p <0,05). The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 1	N	Mean	SD	t	p
Ball Game	35	8,29	1,226	-5,767	0,000
Kaizen Word Game	35	9,57	,884		

Table 4.1.2.5 T-test between the data of Ball Game and Kaizen Word Game post-tests

In the first group, it is seen that the mean of the correct answers of the game-based learning techniques (lean game, Ball Game and Kaizen Word Game) are higher than the Theoretical Kaizen Training correct answers. When the paired samples t-test of Ball Game and the Kaizen Word Game results is analyzed, it is observed that the mean of correct answers of the end-of-training of Kaizen Word Game is higher and there is a statistically significant difference between two trainings.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of Kaizen Word Game implemented in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of Kaizen Word Game implemented in group 2.*

The training given in group 1 was given to group 2 in the reverse cycle. In Group 2, Kaizen training was started with Kaizen Word Game. In Table 4.1.2.6, the number of correct answers of group 2's Kaizen Word Game pre-and-post tests, and paired samples t-test are given. According to the results of t-test, there is statistically significant difference between the correct answers of pre-and-post test of Kaizen Word Game in group 2 (t: -3,180; p <0,05). After Kaizen Word Game implemented into the training, it is seen that the mean of correct answers increased significantly. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 2		N	Mean	SD	t	p
Kaizen Word Game	Pre-test	16	6,38	2,029	-3,180	0,006
	Post-test	16	7,94	1,652		

Table 4.1.2.6 T-test for pre-and post-test of Kaizen Word Game in group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of Ball Game implemented in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and post-test of Ball Game implemented in group 2.*

In group 2, Ball Game was given to employees in the second training. T-test of the analysis of correct answers of this trainings' pre-and-post-tests presented in Table 4.1.2.7. According to the results of the t-test, there is statistically significant difference between the correct answers of group 2 Ball Game pre-and-post test (t: -2,959; p <0,05). After Ball Game implemented into the training, it is observed that the mean of correct answers increased significantly. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 2		N	Mean	SD	t	p
Ball Game	Pre-test	16	7,63	1,258	-2,959	0,010
	Post-test	16	8,89	1,014		

Table 4.1.2.7 T-test for pre-and post-test of Ball Game in group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and post-test of Theoretical Kaizen Training implemented in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and post-test of Theoretical Kaizen Training implemented in group 2.*

Theoretical Kaizen Training was given to the employees in group 2 as the last training. The paired samples t-test of correct answers of pre-and-post test of group 2 Kaizen training, shown in Table 4.1.2.8. According to the results of t-test, there is statistically significant difference between the number of correct answers of group 2 theoretical training pre-and post-test (t: -4,869; p <0,05). After Theoretical Kaizen Training implemented to the participants, the mean of scores increased significantly. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 2		N	Mean	SD	t	p
Theoretical Kaizen Training	Pre-test	16	8,44	1,365	-4,869	0,000
	Post-test	16	9,31	1,352		

Table 4.1.2.8 T-test for pre-and-post test of Theoretical Kaizen Training in group 2

When the increase between pre-and-post test results of three training taken by group 2 were analyzed, the highest increase of mean is seen in Kaizen Word Game as in the group 1.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of Ball Game and Kaizen Word Game post-tests.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the number of correct answers of Ball Game and Kaizen Word Game post-tests.*

In order to compare the Kaizen Word Game and Ball Game given in group 2, paired samples t-test was performed by using the correct answers of post-test and are given in Table 4.1.2.9. According to the results of the t-test, there is no statistically significant difference between the data of correct answers of the Kaizen Word Game and Ball Game pre-and- post tests of the participants in Group 2 (t:, -1,772; p>0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 2	N	Mean	SD	t	p
Kaizen Word Game	16	7,94	1,652	-1,772	0,097
Ball Game Training	16	8,69	1,014		

Table 4.1.2.9 T-test between the data of Kaizen Word Game and Ball Game post-tests

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Ball Game post-tests.*

Paired samples t-test was also performed with the data of correct answers of Ball Game and Theoretical Kaizen Training post-test in group 2 and is given in table 4.1.2.10. According to the results of the t-test, there is not any statistically significant difference between the data of correct answers of Ball Game and Theoretical Kaizen Training post-tests in group 2 (t: -1,619; p>0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 2	N	Mean	SD	t	p
Ball Game Training	16	8,69	1,014	-1,619	0,126
Theoretical Kaizen Training	16	9,31	1,352		

Table 4.1.2.10 T-test between the data of Theoretical Kaizen Training and Ball Game post-tests

The improvement rates of the number of correct answers of group 1 and group 2 trainings are shown in Table 4.1.2.11. Kaizen Word Game has the best improvement rate in Group 1 and 2. Theoretical Kaizen Training, on the other hand, has the lowest improvement rate.

Group 1	Pre-Test Mean	Post-Test Mean	Difference	Improvement Rate (%)
Theoretical Kaizen Training	7,23	7,57	0,34	5%
Ball Game	7,71	8,29	0,58	7%
Kaizen Word Game	8,80	9,57	0,77	8%
Group 2				
Kaizen Word Game	6,38	7,94	1,56	20%
Ball Game	7,63	8,69	1,06	12%
Theoretical Kaizen Training	8,44	9,31	0,87	9%

Table 4.1.2.11 The improvement rates of group 1 and group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of group 1 and group 2 post-tests.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the number of correct answers of group 1 and group 2 post-tests.*

Table 4.1.2.12 includes the independent samples t-test performed with correct answers of Group 1 and 2 post-tests. According to the results of the t-test, there is not any statistically significant difference between the data of correct answers of Group 1 and 2 post-tests and the groups (t: 0,817; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

	N	Mean	SD	t	p
Group 1	35	9,57	0,884	0,817	0,418
Group 2	16	9,31	1,352		

Table 4.1.2.12 T-test between the data of post-test of group 1 and group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of the Theoretical Kaizen Training implemented in group 3.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of the Theoretical Kaizen Training implemented in group 3.*

The data of the Theoretical Kaizen Training pre-and-post test were analyzed with paired samples t-test (Table 4.1.2.13). According to the results of the t-test, there is statistically significant difference between the pre-and-post test scores of theoretical training given to Group 3 participants (t: -3,112; p <0,05).The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 3		N	Mean	SD	t	p
Theoretical Kaizen Training	Pre-test	34	6,15	1,909	-3,112	0,004
	Post-test	34	6,68	1,701		

Table 4.1.2.13 T-test for pre-and-post test of Theoretical Kaizen Training in group 3

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the pre-and-post test of the Kaizen Word Game implemented in group 4.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the pre-and-post test of the Kaizen Word Game implemented in group 4.*

Only the Kaizen Word Game was given to the employees in Group 4. (Table 4.1.2.14) According to the results of the paired samples t-test, there is statistically significant difference between the correct answers of Group 4 Kaizen Word Game pre-and-post test (t: -6,758; p <0,05). After Kaizen Word Game implemented to the participants, it is observed that the mean of scores increased significantly. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 4		N	Mean	SD	t	p
Kaizen Word Game	Pre-test	34	6,71	1,801	-6,758	0,000
	Post-test	34	8,91	1,055		

Table 4.1.2.14 T-test for pre-and-post test of Kaizen Word Game in group 4

The improvement rates of the number of correct answers in Group 3 and Group 4 training are presented in Table 4.1.2.15. When examining the improvement rates of Group 3 and 4, the Kaizen Word Game seems to have the best improvement rate.

	Group	Pre-Test Mean	Post-Test Mean	Improvement Rate (%)
Theoretical Kaizen Training	3	6,15	6,68	8%
Kaizen Word Game	4	6,71	8,91	25%

Table 4.1.2.15 The Improvement Rates of Group 3 and Group 4

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Kaizen Word Game post-tests.*

H_1: $\mu \neq \mu_0$ *Tthere is statistically significant difference between the number of correct answers of Theoretical Kaizen Training and Kaizen Word Game post-tests.*

In Table 4.1.2.16, the data of the 3rd Group and 4th Group post-tests, and the data of independent samples t-test are given. According to the t-test results, statistically significant difference seen between the data of correct answers of Group 3 and 4 post-tests and the groups (t: -6,513; p <0,05). There is statistically significant difference between the post-test of theoretical training implemented to the 3rd Group, and the post-test of word game training implemented to the 4th Group. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

	N	Mean	SD	t	p
Group 3	34	6,68	1,701	-6,513	0,000
Group 4	34	8,91	1,055		

Table 4.1.2.16 T-test between the data of post-test of group 3 and 4

When the results of the group 3 and 4 achievement test are analyzed, it is confirmed that the rate of the correct answers for the questions that include the basic concepts is higher in Kaizen Word Game training than the Theoretical Kaizen Training. The questions of achievement tests have also been analyzed. (Table 4.1.2.17) The first 5 questions in the achievement test are related to Lean Production techniques. When the correct answers' rate of the post-test of the first 5 questions is analyzed, it is seen that the rate of correct answers that was given by the employees in Group 4 is higher. The last 5 questions of the test questions are about the Kaizen technique.

When Kaizen questions are analyzed, it is seen that the rate of the correct answers in Kaizen Word Game is higher than the Theoretical Kaizen Training. For example, the definition of kaizen is asked in question 9 and the rate of correct answers is 91% in Kaizen Word Game. The rate of correct answer indicates that theoretical or difficult words have been learned in the Kaizen Word Game. However, in the second question in which 7 basic wastes are asked, the rate of correct answers to this question in Kaizen Word Game is better than the theoretical training. But not sufficient because the rate of giving the correct answers to all questions is expected to be 100%.

Training/Question	Q1 (%)	Q2 (%)	Q3 (%)	Q4 (%)	Q5 (%)	Q6 (%)	Q7 (%)	Q8 (%)	Q9 (%)	Q10 (%)
Kaizen Word Game	100	62	91	100	88	97	88	76	91	97
Theoretical Kaizen Training	100	38	82	85	74	76	74	53	29	56

Table 4.1.2.17 Question-based analysis

Table 4.1.2.18, which consists of improvement rates, is established for comparison of training groups. When the groups are compared in terms of improvement rates, Group 2 and Group 4 shows high improvement rate, Group 3 to which the Theoretical Kaizen Training was given has the lowest improvement rate.

	Pre-Test Mean	Post-Test Mean	Improvement Rate (%)
Group 1	7,23	9,57	24%
Group 2	6,38	9,31	32%
Group 3	6,15	6,68	8%
Group 4	6,71	8,91	25%

Table 4.1.2.18 Improvement rates among the group

The pre-and-post test correct numbers of the groups were analyzed with analysis of covariance (ANCOVA). ANCOVA is an extended version of variance analysis and allows the evaluation of differences between groups while keeping the covariate variable under control statistically. In this analysis, independent variable is groups, dependent variable is post-test and covariate variable is pre-test correct number. ANCOVA was used to analyze whether there was a significant difference between pre-test correct numbers and corrected post-test correct numbers.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between post-tests of groups.*
H_1: $\mu \neq \mu_0$ *There is statistically significant difference between post-tests of groups.*

ANCOVA assumptions were checked for pre-and-post test. The groups are independent from each other. The variances of the groups were equal so that the homogeneity of the variances was achieved (Table 4.1.3.19). In-group regression coefficients are equal. According to ANCOVA results in Table 4.1.3.20, there is significant difference between the post-tests corrected according to the pre-tests. (F: 37,748; p<0,05). The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

F	df1	df2	Sig.
1,427	3	115	0,238

Table 4.1.2.19 Levene's test of equality of error variances

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	223,657[a]	4	55,914	48,275	0,000	0,629
Intercept	317,107	1	317,107	273,781	0,000	0,706
Pre-Test	54,145	1	54,145	46,747	0,000	0,291
Group	131,164	3	43,721	37,748	0,000	0,498
Error	132,041	114	1,158			
Total	8996,000	119				
Corrected Total	355,697	118				
a. R Squared = ,629 (Adjusted R Squared = ,616)						

Table 4.1.2.20 The result of the ANCOVA

When the results of the Bonferroni test in Table 4.1.3.21 are analyzed, it is seen that group 2s’ post-test correct numbers are higher than the other groups. In addition, the average of group 1s' post-test is higher than group 3 and group 4. According to these results, group 2 has the highest post-test correct numbers. The theoretical kaizen training that was used in group 3 has the lowest post-test correct numbers than others. The results of the ANCOVA analysis support improvement rates.

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Group1	group2	-0,057	0,328	1,000	-0,938	0,824
	group3	2,495*	0,266	0,000	1,781	3,208
	group4	0,466	0,261	0,458	-0,234	1,166
Group2	group1	0,057	0,328	1,000	-0,824	0,938
	group3	2,552*	0,327	0,000	1,675	3,428
	group4	0,523	0,327	0,673	-0,354	1,401
Group3	group1	-2,495*	0,266	0,000	-3,208	-1,781
	group2	-2,552*	0,327	0,000	-3,428	-1,675
	group4	-2,028*	0,263	0,000	-2,734	-1,323
Group4	group1	-0,466	0,261	0,458	-1,166	0,234
	group2	-0,523	0,327	0,673	-1,401	0,354
	group3	2,028*	0,263	0,000	1,323	2,734

Based on estimated marginal means

*. The mean difference is significant at the 0,05 level. b. Adjustment for multiple comparisons: Bonferroni.

Table 4.1.2.21 The results of the Bonferroni test

Multiple regression analysis was used to analyze the effect of demographic characteristics such as age, experience, and graduation on pre-and-post test correct numbers. The relations between multiple independent variables, age, experience and graduation, and the dependent variable, pre-and-post test analyzed. Firstly, multiple regression analysis was performed for pre-test.

H_0: $\beta_1=\beta_2=\beta_3=0$ Age, experience and graduation have no effect on pre-test.

H_1: $\beta \neq 0$ At least one of the variances (age, experience and graduation level) have effect on the pre-test.

Model: $Y_i = \beta_0 + \beta_1 x_1 + \beta_2 x_1 + \beta_3 x_3 + e_i$ **(4.1.2.1)**

$$Y_i\ (\text{pre-test}) = \beta_0 + \beta_1 x_1\ (\text{age}) + \beta_2 x_1 (\text{experience}) + \beta_3 x_3\ (\text{graduation}) + e_i$$

The regression model established to test the effect of independent variables on the pre-test shown statistically significant (Table 4.1.3.22) ($F=5,420$; $p<0,05$). The H_0 hypothesis is rejected and the H_1 hypothesis is acceptable.

Model 1	Sum of Squares	df	Mean Square	F	Sig.
Regression	51,637	3	17,212	5,420	0,002[b]
Residual	365,237	115	3,176		
Total	416,874	118			

a. Dependent Variable: pre-test b. Predictors: (Constant), Graduation, Age, Experience

Table 4.1.2.22 The results of ANOVA test of pre-test

When the independent variables were analyzed separately, the effect of age on the pre-test ($\beta = 0,137$; $t = 1,326$; $p> 0,05$), and the effect of experience on the pre-test was not statistically significant ($\beta = -0,168$; $t = -1,567$; $p> 0,05$).However, it was found that the graduation status had statistically significant and positive effect on the pre-test ($\beta = 0,371$; $t = 4,003$; $p <0,05$) and shown in table 4.1.2.23. When the explanatory power of these three variables in the model is examined, the explanatory power of the model is 10.1% and shown in table 4.1.2.24.

Model 1	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3,193	1,019		3,135	0,002
Age	0,473	0,357	0,137	1,326	0,187
Experience	-0,283	0,181	-0,168	-1,567	0,120
Graduation	1,081	0,270	0,371	4,003	0,000

Table 4.1.2.23 The results of multiple regression analysis of pre- test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,352[a]	0,124	0,101	1,782

Table 4.1.2.24 Model summary of pre-test

Secondly, Then multiple regression analysis was performed for post-test.

H_0: $\beta_1=\beta_2=\beta_3= 0$ *Age, experience and graduation have no effect on the post-test.*

H_1: $\beta \neq 0$ At least one of the variances (age, experience and graduation l level) have effect on the pre-test.

Model: Yi =β0+ β1x1+β2x1+β3x3+ei **(4.1.2.2)**

Yi (post-test) =β0+β1 x1 (age) + β2 x1(experience) +β3 x3 (graduation) +ei

As a result of multiple regression analysis, it was found that independent variables had a statistically significant relationship with the posttest and are shown in table 4.1.2.25 ($F=3,742$; $p<0,05$). Since the significance value is less than 0.05, the H_0 is rejected and it is concluded that the independent variable (s) allows to estimate the Y variable remarkably and H_1 is accepted.

Model 1	Sum of Squares	df	Mean Square	F	Sig.
Regression	31,634	3	10,545	3,742	0,013[b]
Residual	324,063	115	2,818		
Total	355,697	118			

a. Dependent Variable: post-test b. Predictors: (Constant), Graduation, Age, Experience

Table 4.1.2.25 The results of ANOVA test of post-test

On the other hand, when the individual significance tests were examined, it was found that age has no affect on post-test and was not statistically significant (β = 0,013; t = 0,123; p> 0.05), the experience had statistically significant and negative effect on the post-test (β = -0,315; t = -2,888; p <0,05) and lastly, it was found that graduation status has no affect on post-test and it was not statistically significant (β = 0,060; t = 0,633; p>0,05) and shown in table 4.1.2.26. When the explanatory power of these three variables is examined, the explanatory power of the model is 6.5% and shown in table 4.1.2.27.

	Unstandardized Coefficients		Standardized Coefficients		
Model1	B	Std. Error	Beta	t	Sig.
(Constant)	9,005	0,959		9,386	0,000
Age	0,041	0,336	0,013	0,123	0,902
Experience	-0,492	0,170	-0,315	-2,888	0,005
Graduation	0,161	0,254	0,060	0,633	0,528

Table 4.1.2.26 The results of multiple regression analysis of post- test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0,298[a]	0,089	0,065	1,679

Table 4.1.2.27 Model summary of post-test

4.1.3 The Results of End-of-Training Outcomes

The employees, who received training, evaluate the trainings at the end with Likert Scale (range of 5, very satisfied to 1, very unsatisfied). There is a training achievement test in section A and there are end-of-training outcomes in section B of the evaluation form. An evaluation can be made on the outcomes of training, which are gained by receiving the end-of-training outcomes. End-of-training outcomes are given in Table 4.1.3.1.

B. End-of-Training Outcomes	
The training provided positive contributions to my professional development.	5 □ 4□ 3□ 2□ 1□
The training provided positive contributions to my personal development.	5 □ 4□ 3□ 2□ 1□
The training helped me gain new information and skills.	5 □ 4□ 3□ 2□ 1□
The training increased my motivation.	5 □ 4□ 3□ 2□ 1□
The training helped me gain new information and skills that I can apply in my institution.	5 □ 4□ 3□ 2□ 1□
The training helped me gain professional information and skills that I can share with my colleagues.	5 □ 4□ 3□ 2□ 1□
The training increased my interest in the subject.	5 □ 4□ 3□ 2□ 1□

Table 4.1.3.1 End-of-training outcomes

In all of the groups, the end-of-training outcomes are received from the participants after the training. The mean scores of the seven criteria was used to analyze the quality of the training.

End-of-training outcomes were analyzed statistically and the data has normal distribution. Paired samples t-test and independent samples t-test were used in statistically analysis.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Theoretical Kaizen Training and Ball Game outcomes in group1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Theoretical Kaizen Training and Ball Game outcomes in group 1.*

The training outcomes of the training carried out in Group 1 were analyzed between themselves. In Table 4.1.3.2, there is paired samples t-test that is prepared with the data of the training outcomes of Theoretical Kaizen Training and Ball Game performed in Group 1. According to the results of the t-test, there is statistically significant difference between end-of-training outcomes of the Theoretical Kaizen Training and Ball Game (t: -2,580; p >0,05). The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

Group 1	N	Mean	SD	t	p
Theoretical Kaizen Training	35	4,58	,510	-2,580	0,014
Ball Game	35	4,79	,444		

Table 4.1.3.2 T-test for outcomes of Theoretical Kaizen Training and Ball Game of group 1

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Ball Game and Kaizen Word Game outcomes in group 1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Ball Game and Kaizen Word Game outcomes in group 1.*

Table 4.1.3.3 includes the t-test for end-of-training outcomes of Ball Game and Kaizen Word Game in Group 1. According to the results of the t-test, there is no statistically significant difference between end-of-training outcomes of Ball Game and Kaizen Word Game (t: 0,211; p >0,05). The hypothesis H_0 is accepted and the hypothesis H1 is rejected.

Group 1	N	Mean	SD	t	p
Ball Game	35	4,79	,444	0,211	0,834
Kaizen Word Game	35	4,78	,449		

Table 4.1.3.3 T-test for outcomes of Ball Game and Kaizen Word Game of group 1

When we evaluate the mean of the training outcomes in Group 1, it is seen that the mean of scores of the training, which include lean games, is higher than the Theoretical Kaizen Training outcomes.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between Kaizen Word Game and Ball Game outcomes in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between Kaizen Word Game and Ball Game outcomes in group 2.*

In Table 4.1.3.4, paired samples t-test for Group 2 training outcomes of the Kaizen Word Game and Ball Game is given. According to the results of t-test, there was no statistically significant difference between the end-of-training outcomes of Ball Game and the Kaizen Word Game in group 2 (t: -0,686; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected

Group 2	N	Mean	SD	t	p
Kaizen Word Game	16	4,69	0,393	-0,686	0,503
Ball Game	16	4,57	0,541		

Table 4.1.3.4 T-test for outcomes of Kaizen Word Game and Ball Game of group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between Ball Game and Theoretical Kaizen Training outcomes in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between Ball Game and Theoretical Kaizen Training outcomes in group 2.*

Paired samples t-test for training outcomes of the group 2 Ball Game and Theoretical Kaizen Trainings are shown in Table 4.1.3.5. According to the results of the t-test, there is no statistically significant difference between the end-of-training outcomes of Ball Game and Theoretical Kaizen Trainings (t: 0,727; p>0,05). The hypothesis H_0 is accepted and the hypothesis H1 is rejected.

Group 2	N	Mean	SD	t	p
Ball Game	16	4,57	0,541	0,727	0,479
Theoretical Kaizen Training	16	4,68	0,366		

Table 4.1.3.5 T-test for outcomes of Ball Game and Theoretical Kaizen Training of group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between end-of-training outcomes of Group 1 and Group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between end-of-training outcomes of Group 1 and Group 2.*

In order to compare the training groups, the end-of-training outcomes between-groups were analyzed. Independent samples t-test for the end-of-training outcomes of group 1 and group 2 are presented in Table 4.1.3.6. According to the results of the t-test, there is no statistically significant difference between end-of-training outcomes of Group 1 and Group 2 (t: 0,752; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H1 is rejected.

	N	Mean	SD	t	p
Group 1	35	4,784	0,449	0,752	0,456
Group 2	16	4,688	0,367		

Table 4.1.3.6 T-test for the end-of-training outcomes of group 1 and group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between end-of-training outcomes of Group 3 and Group 4.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between end-of-training outcomes of Group 3 and Group 4.*

Table 4.1.3.7 shows the independent samples t-test for the end-of-training outcomes of Group 3 and 4. According to the results of the t-test, there is statistically significant difference between the end-of-training outcomes of Group 3 and 4 (t: -2,832; p <0,05). At the same time, it can be said that the training outcomes of Kaizen Word Game in Group 4 are remarkably higher than the Theoretical Kaizen Training outcomes in Group 3. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

	N	Mean	SD	t	p
Group 3	34	4,42	0,546	-2,832	0,006
Group 4	34	4,77	0,452		

Table 4.1.3.7 T-test for the end-of-training outcomes of group 3 and group 4

According to the results of the t-test, there is no significant difference between the end-of-training outcomes of Group 1 and Group 2, but there is significant difference between the end-of-training outcomes of Group 3 and Group 4. The end-of-training outcomes were evaluated by the participants in seven criteria. Detailed analysis of the criteria was carried out for Group 3 and Group 4. Since the training outcomes in each of the dependent training given in Group 1 and Group 2 were affected by each other, the analysis of criterion-based end-of-training outcomes was performed for Group 3 and Group 4. The mean of scores that were given according to the criteria of end-of-training outcomes by participants in Group 3 and Group 4 was calculated. The mean of the criteria for end-of-training outcomes of Group 3 and Group 4 are given in Table 4.3.1.8. When comparing it by Group 3 and Group 4 end-of-training outcomes criteria, Kaizen Word Game in Group 4 is better in terms of end-of-training outcomes.

End-of-Training Outcomes	**Group 3**	**Group 4**
1. The training provided positive contributions to my professional development.	4,50	4,79
2. The training provided positive contributions to my personal development.	4,38	4,76
3. The training helped me gain new information and skills.	4,35	4,76
4. The training increased my motivation.	4,41	4,82
5. The training helped me gain new information and skills that I can apply in my institution.	4,06	4,74
6. The training helped me gain new professional information and skills that I can share with my colleagues.	4,18	4,68
7. The training increased my interest in the subject.	4,50	4,85

Table 4.3.1.8 The mean of the criteria for end-of-training outcomes of group 3 and group 4

4.1.4 General Training Evaluation Results

In the study, the employees who received training were asked to evaluate the training in general within the range of 5 (excellent) to 1 (poor) at section C of the end-of-training evaluation part. With general training evaluation, different factors such as achievement test, end-of-training gains, facilitator, training environment, duration of the training, training materials, participants are evaluated together. In all the groups, general training evaluations were received from the participants at the end-of-training evaluations.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Theoretical Kaizen Training and Ball Game general training evaluations in group 1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Theoretical Kaizen Training and Ball Game general training evaluations in group 1.*

The general evaluations of the training which were carried out in Group 1 were analyzed between themselves. In Table 4.1.4.1, there is paired samples t-test prepared with the data of general training evaluations of Theoretical Kaizen Training and Ball Game. According to the results of the t-test, there is no statistically significant difference between the general training evaluations of group 1, Theoretical Kaizen and Ball Games (t: -1,966; p >0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 1	N	Mean	SD	t	p
Theoretical Kaizen Training	35	4,31	0,900	-1,966	0,58
Ball Game	35	4,60	0,651		

Table 4.1.4.1 T-test for general training evaluations of Theoretical Kaizen Training and Ball Game of group 1

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Ball Game and Kaizen Word Game general training evaluations in group1.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Ball Game and Kaizen Word Game general training evaluations in group1.*

According to the results of the paired samples t-test performed for the Ball Game and Kaizen Word Games, there is no statistically significant difference between the general evaluations of Ball Game and Kaizen Word Game of Group 1 (t: 1,152; p >0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 1	N	Mean	SD	t	p
Ball Game	35	4,60	0,651	1,152	0,257
Kaizen Word Game	35	4,74	0,505		

Table 4.1.4.2 T-test for general evaluations of Ball Game and Kaizen Word Game of group 1

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Ball Game and Kaizen Word Game general training evaluations in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Ball Game and Kaizen Word Game general training evaluations in group 2.*

Paired samples t-test for the general training evaluations of the Kaizen Word Game and Ball Game in Group 2 are given in Table 4.1.4.3. According to the results of the t-test, there is no statistically significant difference between general evaluations of Ball Game and Kaizen Word Game (t: 1,775; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 2	N	Mean	SD	t	p
Kaizen Word Game	16	4,69	0,505	1,775	0,096
Ball Game	16	4,38	0,619		

Table 4.1.4.3 T-test for general evaluations of Ball Game and Kaizen Word Game of group 2

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the Ball Game and Theoretical Kaizen Training general training evaluations in group 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the Ball Game and Kaizen Word Game general training evaluations in group 2.*

Paired samples t-test for the general training evaluations of Ball Game and Theoretical Kaizen Training performed in Group 2 are presented in Table 4.1.4.4. According to the results of the t-test, there is no statistically significant difference between general training evaluations of Group 2 Ball Game and Theoretical Kaizen Training (t: 0,522; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H_1 is rejected.

Group 2	N	Mean	SD	t	p
Ball Game	16	4,50	0,632	0,522	0,609
Theoretical Kaizen Training	16	4,38	0,619		

Table 4.1.4.4 T-test for general training evaluations of Ball Game and Theoretical Kaizen Training of group 2

H_0: $\mu = \mu_0$ There is no statistically significant difference between general training evaluations of Group 1 and Group 2.

H_1: $\mu \neq \mu_0$ There is statistically significant difference between general training evaluations of Group 1 and Group 2.

Independent samples t-test for the general training evaluations of group 1 and group 2 was also done. (Table 4.1.4.5) As a result of the t-test, there is no statistically significant difference between the general training evaluations of group 1 and group 2 (t: 1,470; p> 0,05). The hypothesis H_0 is accepted and the hypothesis H1 is rejected.

	N	Mean	SD	t	p
Group 1	35	4,74	0,505	1,470	0,148
Group 2	16	4,50	0,632		

Table 4.1.4.5 T-test for the general training evaluations of group 1 and group 2

H_0: $\mu = \mu_0$ There is no statistically significant difference between general training evaluations of Group 3 and Group 4.

H_1: $\mu \neq \mu_0$ There is statistically significant difference between general training evaluations of Group 3 and Group 4.

Independent samples t-test for the general training evaluations of group 3 and group 4 was carried out as well. (Table 4.1.4.6) As a result of the t-test, there is statistically significant difference between the general training evaluations of group 3 and group 4 (t: -4,401; p<0,05). At the same time, it is seen that the general training evaluations of Group 4 are significantly higher than Group 3.

	N	Mean	SD	t	p
Group 3	34	3,94	0,814	-4,401	0,000
Group 4	34	4,68	0,535		

Table 4.1.4.6 T-test for the general training evaluations of group 3 and group 4

4.1.5 Analysis of Training Outputs

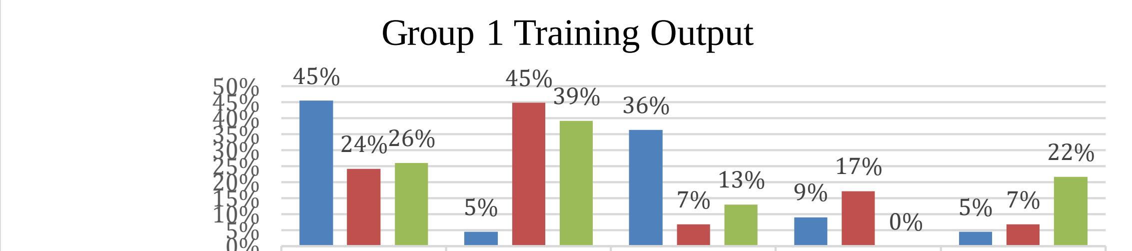
At section D of the end-of-training evaluation part, the question of "Can you describe the output of the training in one word?" was asked to the employees who received training. These words written by the employees at the end of the training are the data that can be used to analyze whether the training has reached its purpose or what the employees have understood from the training. Employees wrote one or more words as output. The words written by the employees were analyzed and grouped. The words written by the employees who received training were grouped under the titles, "Educational and Instructional, Fun and Educational, Kaizen, Respect for Human, Teamwork". While creating groups, words that were similar or related to the titles are brought together under the same title. For example; Words such as "Improvement, Waste, Kaizen, Sustainability, Development, and Productivity" were listed under the title of Kaizen. Examples of the words in the training output groups are given in Table 4.1.5.1.

Group of Training Outputs				
Kaizen	**Teamwork**	**Fun and Educational**	**Educational and Instructional**	**Respect For Human**
Improvement	Compatible	Fun and Instructional	Useful	Human
Waste	Team Idea	Very good	Educational	Respect
Sustainability	Teamwork	Excellent	Descriptive	Value
Development	Team spirit	Fun and Educational	Contributive	Respect For Human
Productivity	To be "We"	Excellent game	Instructional	Idea

Table 4.1.5.1 The words in training output groups

In the end-of-training evaluation, the field of training output is not required to be filled out. Therefore, not all employees wrote training output, and some employees left section D of the training evaluation blank. For example, while 17 employees wrote training output in Theoretical Kaizen Training given to 34 employees in group 3, 22 employees wrote training output in Kaizen Word Game given to 34 employees in group 4. In this respect, the output groups of the employees who gave a reflection were analyzed in percentages.

In Figure 4.1.5.1, the outputs of the training carried out in Group 1 are given in percentages. When Group 1 reflection were analyzed, 45% of the employees in Theoretical Kaizen Training find the training as Education and Instructional. On the other hand, in Ball Game and Kaizen Word Game, which are game-based learning techniques employees reflect the training as Fun and Educational. At the same time, in Group 1, it is seen that the Kaizen Word Game Training reflection word is Teamwork at a rate of 22%.



	Educational and Instructional	Fun and Educational	Kaizen	Respect for Human	Teamwork
Teorical Training	45%	5%	36%	9%	5%
Ball Game	24%	45%	7%	17%	7%
Kaizen World Game	26%	39%	13%	0%	22%

Figure 4.1.5.1 Group 1 training output graph

In Figure 4.1.5.2, the outputs of the training carried out in group 2 are given in percentages. Fun and Educational, Kaizen and Team Work training output come into prominence in Kaizen Word Game of group 2. In Ball Game, Educational and Instructional and Kaizen outputs are seen to have a higher rate than others. When we analyze the Theoretical Kaizen Training, on the other hand, we see that Kaizen and Respect for Human output come into prominence. In the content of Theoretical Kaizen, the Lean Production management system is explained in general, and respect for Human is emphasized. Therefore, Respect for Human is the expected output in Theoretical Kaizen Training.

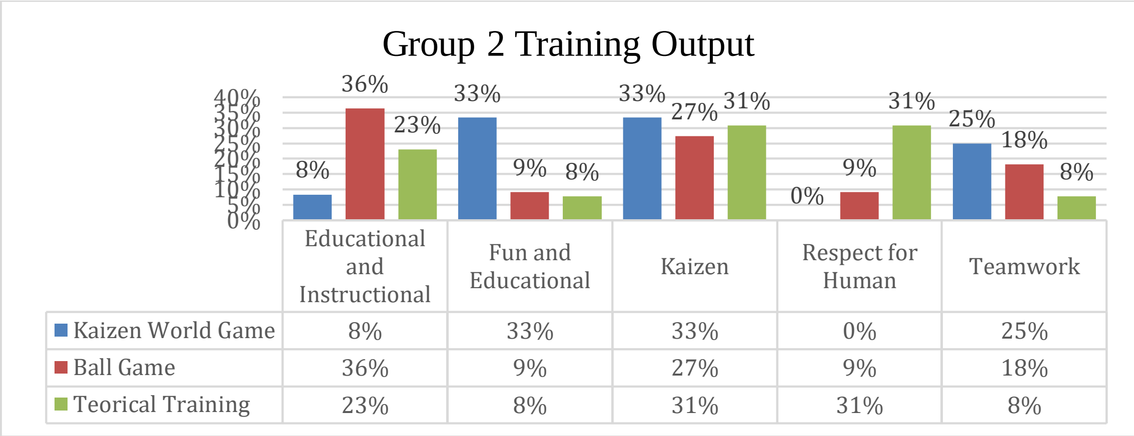


Figure 4.1.5.2 Group 2 training output graph

In Figure 4.1.5.3, group 3, and group 4 training output s are presented. In the evaluation performed at the end of the Theoretical Kaizen Training given in Group 3, it is seen that 47% of the employees who wrote the training output gave the answer as Kaizen and 29% gave the answer as Respect for Human. In Kaizen Word Game given in Group 4, it is seen that the Fun and Educational training output group has a higher rate than other groups. In this respect, it can be said that Kaizen Word Game is found to be fun and educational by employees.

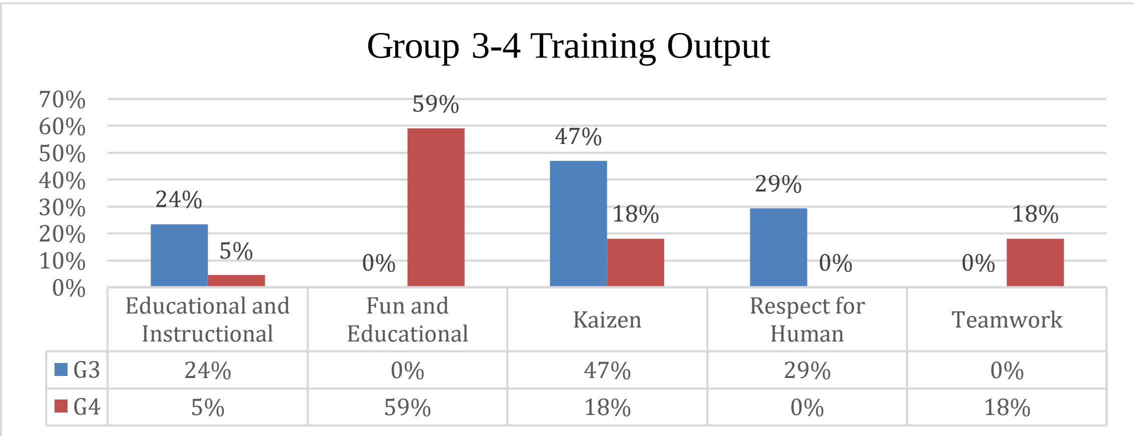


Figure 4.1.5.3 Group 3-group 4 training output graph

When the training outputs are analyzed in general, the words of Kaizen and Respect for Human were given as an output for the theoretical training; the words of fun, educational and instructive were given as an output for the Ball Game. The training outputs of Kaizen Word Game, on the other hand, are fun, educational, and teamwork.

4.2 Effect of Lean Production Training on KPI in Kaizen Word Game

"Kaizen Word Game", which was designed within the scope of the study, was implemented to 50 blue-collar employees in 13 teams. There are 3 employees in 2 teams and 4 employees in 11 teams. The KPI (Key Performance Indicator) data were obtained from employees who were in the training groups and had not previously received kaizen training. Accordingly, KPI (key performance Indicator) data were collected during the training from the employees who took Kaizen Word Game in training group 2 and training group 4 by using data gathering forms. 1216 data were analyzed. The example of data set is included in Appendix 7.

KPI analysis is performed to see the effect of Lean Production techniques and to measure the performance of the game. There are 3 game outputs and KPI. Game outputs are cycle time (guessing the time of 4 cards), completion time (delivery time of 12 cards, namely, 3 products) and the number of quality errors. KPIs calculated from Kaizen Word Game outputs are net completion time, the coefficient of variation of cycle times, and the number of quality errors.

In section 1 of the Kaizen Word Game designed within the scope of the study, employees implemented Kaizen Word Game by their competencies. At the end of the 1st section, training for brief information about Lean Production techniques and kaizen was given. Kaizen Word Game's 2nd and 3rd sections were implemented after training for brief information about Lean Production techniques and Kaizen. The section 1 and 2 of Kaizen Word Game compared in KPI analysis. The completion time of teams in each section is shown in Figure 4.2.1. As seen in Figure 4.2.1, time to complete the products for teams were shortened in the sections after taking Lean Production techniques. Low completion time does not always mean that the process is well [186]. Therefore, other factors affecting training performance will be analyzed.

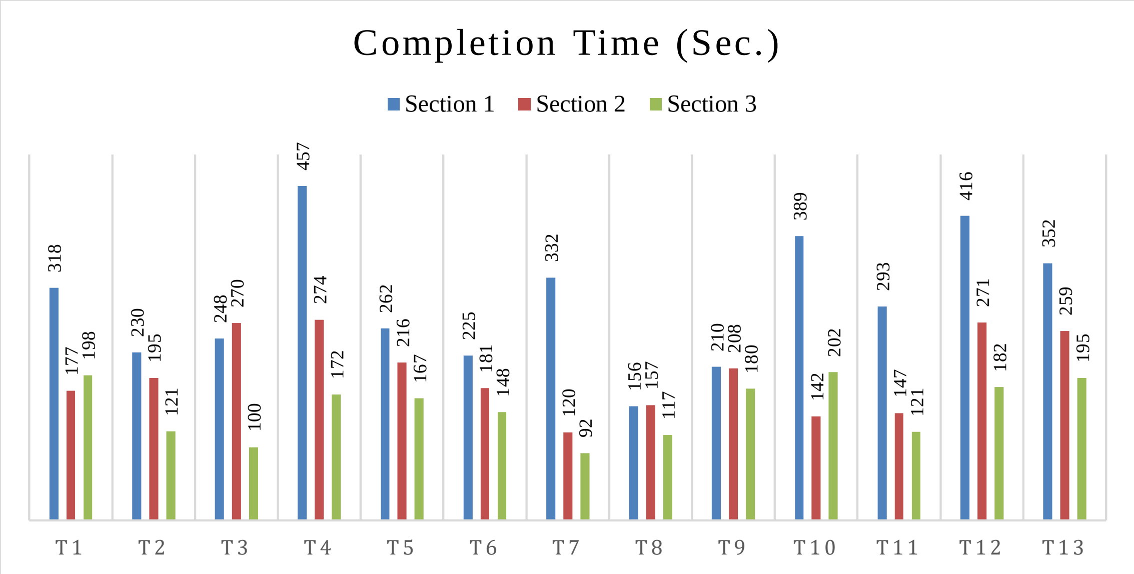


Figure 4.2.1 Completion time graph

The goal in Kaizen Word Game is to guess the right 12 cards as soon as possible. To improve completion time, teams explained orange cards that are level 3 difficulty level. When one of the orange Cards is guessed correctly, the team gains 30 seconds. The advantage time of orange card is reflected in the Kaizen Word Game outputs of the teams who explain the orange card. Figure 4.2.2 shows the completion time, which was shortened by 30 seconds because of the orange cards. In case of the orange cards are guessed correctly, their completion time is further shortened. In Figure 4.2.3, the number of known orange cards is given. After Lean Production techniques, the improvements in section 2 and section 3 and the usage of orange cards are increased.

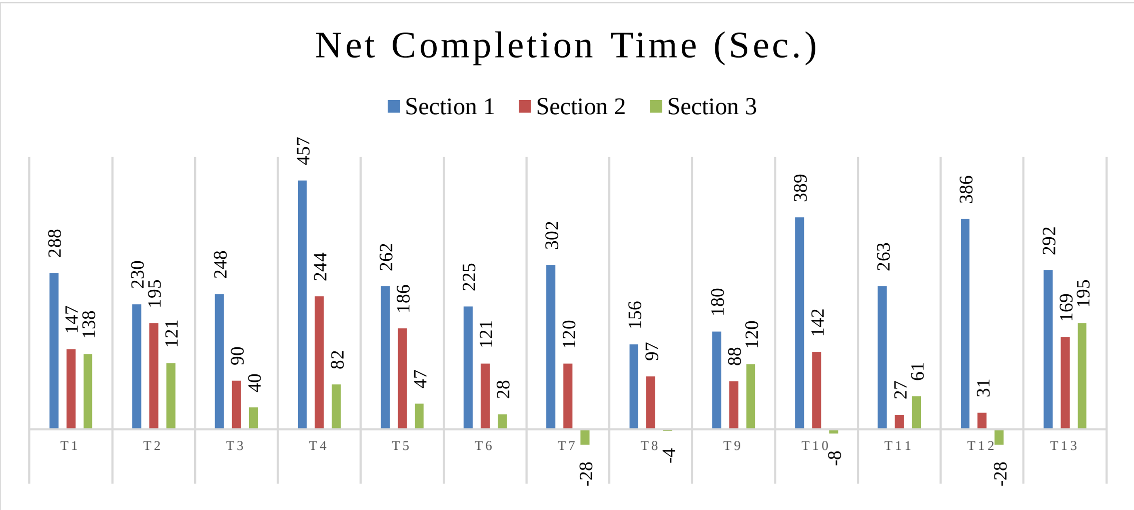


Figure 4.2.2 Net completion time graph

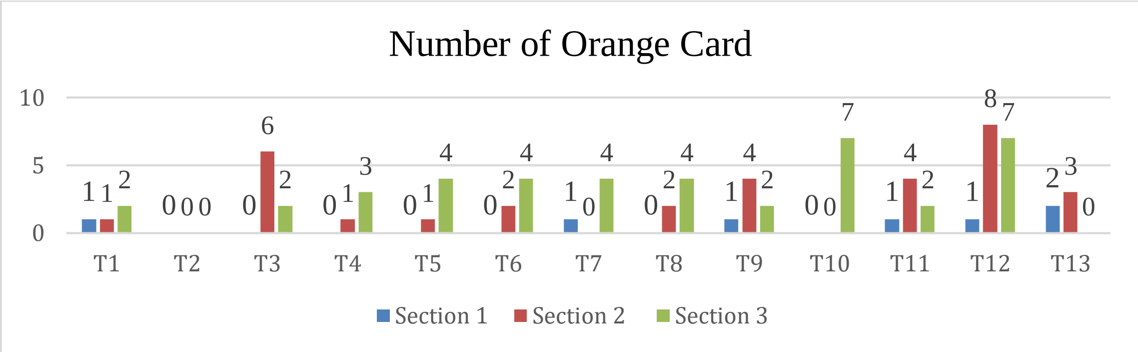


Figure 4.2.3 Number of orange card

The decrease in net completion time of Section 1 and Section 2 is shown in Figure 4.2.2. Whether there is a difference between net completion time of section 1 and section 2 is analyzed by paired samples t-test.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between net completion time of section 1 and section 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between net completion time of section 1 and section 2.*

The t-test was used to analyze whether the use of Lean Production techniques is effective in decreasing net completion time. The paired samples t-test for completion times is presented in Table 4.2.1. According to the results of the t-test, there is a statistically significant difference between the net completion times of section 1 and section 2. Additionally, the mean of completion time shows the decrease in favor of section 2 (t: 6,239, p <0,05). The hypothesis H_0 is rejected and the hypothesis H1 is accepted.

	N	Mean	SD	t	p
Section 1	13	282,84	85,462	6,239	0,000
Section 2	13	127,32	62,834		

Table 4.2.1 T-Test for net completion time

Figure 4.2.4 shows the chart of the cycle time in which the gains from Orange Cards are reflected. Since 12 cards, namely 3 products, are requested for each section in Kaizen Word Game, a team has 9 cycle time in total, and there is a fluctuation in cycle time as seen in Figure 4.2.4.

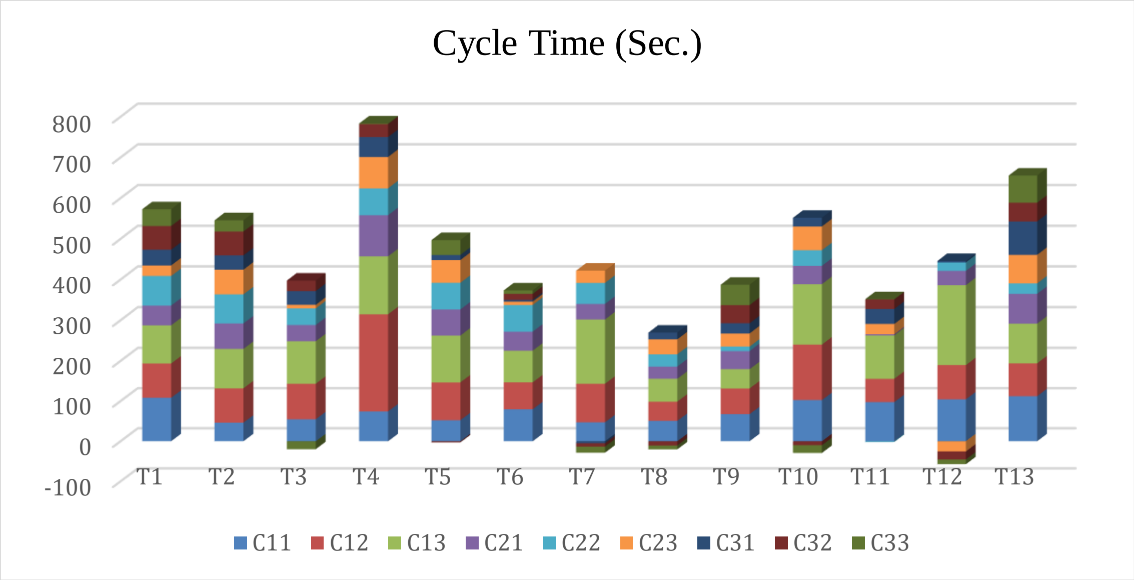


Figure 4.2.4 Cycle time

Coefficient of variation (CV) of cycle time is calculated for 13 teams in both section 1 and 2 (Table 4.2.2). The variability in cycle time is expected to decrease after Lean Production techniques training in Section 2. However, when we look at Table 4.2.2, while there is a decrease in some teams, there is also an increase in some teams. Orange cards used for improvement in the Kaizen Word Game increase the coefficient of variation. Therefore, we cannot say that the use of lean tools reduces the coefficient of variation. For more clear-cut results, a t-test was performed with the Coefficient of Variation (CV) data.

Team	*S1-SD*	*S1-Mean*	*S1-CV*	*S2-SD*	*S2-Mean*	*S2-CV*	*Difference*
T1	11,57	95,86	12,07	23,46	49,00	47,88	-0,36
T2	26,86	76,57	35,08	5,99	64,88	9,23	0,26
T3	25,65	82,81	30,97	18,12	29,85	60,68	-0,30
T4	83,61	152,33	54,89	18,07	81,42	22,19	0,33
T5	32,25	87,46	36,88	5,19	61,85	8,39	0,28
T6	7,01	75,09	9,34	29,16	40,17	72,59	-0,63
T7	56,02	100,63	55,67	10,79	40,04	26,96	0,29
T8	4,75	51,91	9,14	3,68	32,48	11,32	-0,02
T9	10,30	59,87	17,21	16,98	29,31	57,92	-0,41
T10	24,02	129,57	18,54	9,98	47,27	21,11	-0,03
T11	26,06	87,57	29,76	14,48	8,89	162,94	-1,33
T12	59,44	128,73	46,17	31,43	10,22	307,48	-2,61
T13	15,38	97,23	15,82	26,68	56,36	47,33	-0,32

Table 4.2.2 Coefficient of variations (CV) of cycle time for in phases 1 and 2

Paired samples t-test of the Coefficient of Variations (CV) is included in Table 4.2.3.

H_0: $\mu = \mu_0$ *There is no statistically significant difference between the coefficient of variations of section 1 and section 2.*

H_1: $\mu \neq \mu_0$ *There is statistically significant difference between the coefficient of variations of section 1 and section 2.*

According to the results of the t-test, there is no significant difference between section 1 and section 2 cycle times of the coefficient of variations (CV) (t: -1,644, p <0, 05). The hypothesis H_0 is rejected and the hypothesis H1 is accepted.

	N	Mean	SD	t	p
Section 1	13	28,58	16,501	-1,644	0,126
Section 2	13	65,85	83,424		

Table 4.2.3 T-test of coefficient of variations (CV) of cycle time for section 1 and 2

One of the Kaizen Word Game KPIs is the number of quality errors. In Figure 4.2.5, the numbers of quality errors are seen. It is seen that quality errors of section 2 and section 3 of the teams are reduced with Lean Production techniques, which is given after section 1, and Kaizen Word Game.

Figure 4.2.5 Graph of number of quality errors

This graph in Figure 4.2.5 may not provide a final result, and the number of quality errors should be analyzed statistically. For this reason, t-test was performed for quality errors. Paired samples t-test for the number of quality errors is given in Table 4.2.4.

$H_0: \mu = \mu_0$ There is no statistically significant difference between the quality errors of section 1 and section 2.

$H_1: \mu \neq \mu_0$ There is statistically significant difference between the number of quality errors of Section 1 and Section 2.

According to the results of the t-test, there is a statistically significant difference between the number of quality errors in section 1 and section 2. (t: 5,734, p <0,05). The mean of the number of quality errors is less in section 2. The hypothesis H_0 is rejected and the hypothesis H_1 is accepted.

	N	Mean	SD	t	p
Section 1	13	6,85	2,609	5,734	0,000
Section 2	13	2,23	1,235		

Table 4.2.4 T-Test for the number of quality errors

In accordance with the KPI analysis, we see better results in section 2 and section 3. The completion time and the number of quality errors in section 2 and section 3 are decreased. During training, teams tried to detect and eliminate wastes which are the enemy of Lean Production techniques. The teams used the before-after kaizen forms and the PDCA cycle in training. In Kaizen Word Game, teams performed kaizen applications such as orange card usage and, process sequence change.

Chapter 5

Conclusions and Future Prospects

5.1 Conclusions

Within the scope of this study to facilitate the selection of Lean Production and Lean Six Sigma training and to analyze the effects on learning, the training was implemented in four training groups with different employees. In these training groups, Theoretical Kaizen Training, Ball Game and Kaizen Word Game were used. At the end of these trainings the results were analyzed by taking into consideration that the employees received the Kaizen training for the first time.

When the achievement tests of the training were analyzed, it was seen that the Theoretical Kaizen Training provided 5% improvement in Group 1 and 8% in Group 3. Furthermore, it was confirmed that the percentage of employees answering the questions on Lean Production concepts correctly was low. If we look at the Theoretical Kaizen Training from the view point of educational outcome, it is seen that the outcome of Theoretical Kaizen Training is less than the other training.

It is also seen that the general training evaluations of the Theoretical Kaizen Training are lower when it is compared with the general training evaluations of the other trainings. When the training outputs were analyzed, the words of Kaizen and Respect for Human are predominant for the training outputs of Theoretical Kaizen Training.

When we look at the training in which lean games, game-based learning techniques such as Ball Game and Kaizen Word Game, are used, it is observed that this training has better outcomes than Theoretical Kaizen Training. In the achievement test of Ball Game Training, there is 7% improvement rate in Group 1 and 12% in Group 2. The mean of end-of-training outcome and general training evaluations of Ball Game Training is better than the Theoretical Kaizen Training. However, since Theoretical Kaizen Training was given before Ball Game Training in Group 1, and since Kaizen Word Game was given in Group 2, there might be an impact of these trainings. The comparison of the outcomes of the Theoretical Kaizen Training given in Group 3 and the Kaizen Word Game given in Group 4 gives more explicit results concerning lean games. Also, Ball Game Training outcomes include fun, educational, and instructive words. So, this means that employees find the Ball Game as a lean game, fun and educational.

When the improvement rates of Group 3 and Group 4 achievement tests are examined, Kaizen Word Game with 25% improvement rate seems to have a better improvement rate than Theoretical Kaizen Training. At the same time, we see a better result in favor of Kaizen Word Game when we look at the post-test of the Theoretical Kaizen Training implemented in Group 3, and the post-test of the Kaizen Word Game implemented in Group 4. The percentage of answering correctly to the questions about Lean Production techniques and Kaizen who received Kaizen Word Game is higher than the percentage of Theoretical Kaizen Training. According to the results of the t-test of Group 3 and Group 4 end-of-training outcome and general training evaluation, it can be said that the Kaizen Word Game are remarkably higher than training outcomes and general training evaluation of Theoretical Kaizen Training. The results of the end-of-training outcomes indicate that Kaizen Word Game increases motivation. In Kaizen Word Game outcomes, participants used the words fun, educational, and teamwork to describe their experience. The outcomes show that it is possible to learn while having fun with Kaizen word game.

As a result of multiple regression analysis, it was found that the graduation status of an employee had statistically significant and positive effect on the pre-test. Also, pre-training experience had a statistically significant and negative effect on the post-test.

Group 2 gives the best results with 32% improvement rate compared to other groups according to outcomes of the training. Also, when the results of the ANCOVA test in are analyzed, it is seen that group 2 post-test correct numbers are higher than the other groups. If the company gives 3 training in 180 minutes for Kaizen training, it will be more useful to give the training sequence that Group 2 received. If the company will allocate 60 minutes to Kaizen training and give one training, it will be more appropriate to implement the Kaizen Word Game with a 25% improvement rate. As a result of the study, the company decided to perform 3 training and to implement them with the sequence of Group 2 training in the form of Kaizen Word Game, Ball Game, and Theoretical Kaizen Training.

Improvement of KPIs was achieved after Lean Production and Kaizen World Game training was given. In section 2, net completion time, and the number of quality errors decrease. In trainings, one of the aims of the teams were to detect and eliminate waste, which is the enemy of Lean Production techniques. For that teams used Before-After Kaizen forms and the PDCA cycle. Employees also had the opportunity to use improvement forms. In Kaizen Word Game, teams performed Kaizen implementations such as orange card usage and process sequence change. These below results show that Kaizen Word Game is an effective tool to use for applying Lean Production technique and Lean Games.

5.2 Future Prospects

Nowadays, companies need management systems such as Lean Production and Lean Six Sigma in order to survive in competitive conditions. The success of Lean Production and Lean Six Sigma management systems can be achieved if these management systems become companies' culture.

Employees of the companies are the most important factor for Lean Production and Lean Six Sigma to become the company culture. To increase the ownership of the employees we have to value their thoughts and actions by providing tools to increase their competencies. For this reason, the training of employees is an essential element for Lean Production and Lean Six Sigma management system. If the company provides the right kind of training for its employees, then Lean Production and Lean Six Sigma can become a company culture.

In this study, Kaizen Training was performed and analyzed. For Kaizen training, Kaizen Word Game was designed by using game-based learning techniques. Results showed that Lean Games are open for improvement and Kaizen Word Game will continue to be revised and may be adapted to DMAIC, 5S, SMED.

Trainings that are using game-based learning techniques for Lean Production and Lean Six Sigma systems should continue to be developed, and studies should be carried out to add the magical world of game in to work life.

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APPENDIX

Appendix 1 Data Collection Form

Data Collection Form																				
Team Name:																				
	Section 1					**Section 2**					**Section 3**					**Section 4**				
Team Members Name					**Card Color**					**Card Color**					**Card Color**					**Card Color**
Pass																				
Error																				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				

Appendix 2 PDCA Cycle Form

PDCA Cycle Form						
	EXPLANATION	SOLUTION	IDEA OWNER	PDCA	STATUS	NOT
1						
2						
						

Appendix 3 Before-After Kaizen Form

Before-After Kaizen Form			Date	KAIZEN No
Department Name		Project		
Problem		Situation Analysis		
Solution				
Team Leader Team Members		Dissemination		

BEFORE (Photographs, figures etc. are explained and the situation before the improvement is explained)	AFTER (Photographs, figures etc. are explained and the situation after the improvement is explained)

Spent / TL			Gain/ TL		
	Total			Total	

Quality ☐ 5S ☐ OHS ☐ Capacity ☐ Cost ☐ Maintenance ☐ SMED ☐ POKE YOKE ☐ Other ☐

Appendix 4 Achievement Test

EĞİTİM BAŞLANGIÇ TESTİ	
Eğitimin Adı:	Tarih:
Katılımcının Adı Soyadı:	Bölümü/Unvanı:
A. Eğitim Testi	

1. *"Daha iyi, daha hızlı ve daha ucuz; israfları ortadan kaldıran ve insana saygıyı benimseyen yönetim sistemidir." tanımı aşağıdakilerden hangisidir?*
A) Yalın Üretim
B) Six Sigma
C) Yalın Six Sigma
D) Toplam Kalite Yönetimi
E) İş Sağlığı ve Güvenliği

2.Aşağıdakilerden hangisi Yalın Üretim'in düşmanı olan 7 temel israfdan biri **<u>değildir?</u>**
A) Hata
B) Fazla Üretim
C) Gereksiz Hareket
D) Emniyet Stoğu
E) Bekleme

3."*Yalın Üretim Sisteminin temelinde, israfları yok etme ve ……………… bulunmaktadır."*
Boşluğa aşağıdakilerden hangisi gelir?
A) Ücret
B) Six Sigma
C) İnsana Saygı
D) Suçlama
E) Yalın Six Sigma

4.Aşağıdakilerden hangisi Yalın Üretim'in temel unsurlarından biri **<u>değildir?</u>**
A) Ekip Çalışması
B) Sürekli İyileştirme
C) İnsana Saygı
D) İsrafları Azaltma
E) Stok Tutma

5. i) Küçük Adımlarla İyileştirme
ii) İnsana Saygı
iii) İsrafları Yok Etme
iv) Sürekli İyileştirme
Yukarıdakilerden hangileri Yalın Üretim'in temel unsurları arasındadır?

A) i, ii
B) i, iv
C) ii, iiii, iv
D) Hepsi
E) Hiçbiri

6.Aşağıdakilerden hangisi dünyanın en fakir kaynaklarına sahip ülkelerinden bir tanesi olan Japonya'nın II. Dünya savaşı gibi yıkıcı bir savaştan sonra kendisini toplamak için kullanmış olduğu tekniklerden biridir?
A) Kaizen
B) Stok
C) Bekleme
D) Hatalı Üretim
E) Gereksiz İşlem

7.Aşağıdakilerden hangisi Kaizen'in faydalarından biridir?
A) İsrafların Artması
B) İşlem Süresinin Artması
C) Kalitenin Artması
D) İş Kazasının Artması
E) Stokların Artması

8.Aşağıdakilerden hangisi Kaizen prensiplerinden biridir?
A)Herkesin Katılımı
B)Az Harcayıp, Kat Kat Çok Kazanım
C)Küçük Adımlarla İyileştirme
D)Bilginin Paylaşılması
E)Hepsi

9. *"Veri toplanmasına ve analizine gerek olmadan tecrübeye dayalı olarak kısa sürede yapılan iyileştirmelerdir."* tanımı aşağıdakilerden hangisidir?
A) Tek Nokta Dersi
B) Otonom Bakım
C) Six Sigma
D) Yalın Six Sigma
E) Önce-Sonra Kaizen

10) i)Teslim süresini azaltma
ii) Taşıma sürelerini azaltma
iii)Stokları azaltma
iv) Fireleri azaltma
Yukarıdakilerden hangileri ile ilgili Kaizen yapılabilir?

A) i, ii
B) i, iv
C) ii, iiii, iv
D) Hepsi
E) Hiçbiri

Appendix 5 Evaluation Form

EĞİTİM DEĞERLENDİRME	
Eğitimin Adı:	Tarih:
Katılımcının Adı Soyadı:	Bölümü/Unvanı:
A. Eğitim Testi	
1. *"Daha iyi, daha hızlı ve daha ucuz; israfları ortadan kaldıran ve insana saygıyı benimseyen yönetim sistemidir." tanımı aşağıdakilerden hangisidir?* A) Yalın Üretim B) Six Sigma C) Yalın Six Sigma D) Toplam Kalite Yönetimi E) İş Sağlığı ve Güvenliği **2.**Aşağıdakilerden hangisi Yalın Üretim'in düşmanı olan 7 temel israfdan biri **değildir?** A) Hata B) Fazla Üretim C) Gereksiz Hareket D) Emniyet Stoğu E) Bekleme **3.**"*Yalın Üretim Sisteminin temelinde, israfları yok etme ve ……………… bulunmaktadır.*" Boşluğa aşağıdakilerden hangisi gelir? A) Ücret B) Six Sigma C) İnsana Saygı D) Suçlama E) Yalın Six Sigma **4.**Aşağıdakilerden hangisi Yalın Üretim'in temel unsurlarından biri **değildir?** A) Ekip Çalışması B) Sürekli İyileştirme C) İnsana Saygı D) İsrafları Azaltma E) Stok Tutma **5.** i) Küçük Adımlarla İyileştirme ii) İnsana Saygı iii) İsrafları Yok Etme iv) Sürekli İyileştirme Yukarıdakilerden hangileri Yalın Üretim'in temel unsurları arasındadır? A) i, ii B) i, iv C) ii, iiii, iv D) Hepsi E) Hiçbiri	**6.**Aşağıdakilerden hangisi dünyanın en fakir kaynaklarına sahip ülkelerinden bir tanesi olan Japonya'nın II. Dünya savaşı gibi yıkıcı bir savaştan sonra kendisini toplamak için kullanmış olduğu tekniklerden biridir? A) Kaizen B) Stok C) Bekleme D) Hatalı Üretim E) Gereksiz İşlem **7.**Aşağıdakilerden hangisi Kaizen'in faydalarından biridir? A) İsrafların Artması B) İşlem Süresinin Artması C) Kalitenin Artması D) İş Kazasının Artması E) Stokların Artması **8.**Aşağıdakilerden hangisi Kaizen prensiplerinden biridir? A)Herkesin Katılımı B)Az Harcayıp, Kat Kat Çok Kazanım C)Küçük Adımlarla İyileştirme D)Bilginin Paylaşılması E)Hepsi **9**. *"Veri toplanmasına ve analizine gerek olmadan tecrübeye dayalı olarak kısa sürede yapılan iyileştirmelerdir."* tanımı aşağıdakilerden hangisidir? A) Tek Nokta Dersi B) Otonom Bakım C) Six Sigma D) Yalın Six Sigma E) Önce-Sonra Kaizen **10)** i)Teslim süresini azaltma ii) Taşıma sürelerini azaltma iii)Stokları azaltma iv) Fireleri azaltma Yukarıdakilerden hangileri ile ilgili Kaizen yapılabilir? A) i, ii B) i, iv C) ii, iiii, iv D) Hepsi E) Hiçbiri

*****Değerlendirmelerinizi size en uygun seçeneği 5 ile 1 arasında işaretleyerek yapınız.** **5 - çok iyi 4 – iyi 3 – orta 2 - iyi değil 1 - hiç iyi değil**

B. Eğitim Sonu Kazanımlar	
Eğitim mesleki gelişimime olumlu katkılar sağladı.	5 □ 4□ 3□ 2□ 1□
Eğitim kişisel gelişimime olumlu katkılar sağladı.	5 □ 4□ 3□ 2□ 1□
Eğitim, yeni bilgi ve beceriler kazandırdı.	5 □ 4□ 3□ 2□ 1□
Eğitim, motivasyonumu arttırdı.	5 □ 4□ 3□ 2□ 1□
Eğitim kurumumda uygulayabileceğim yeni bilgi ve beceriler kazandırdı.	5 □ 4□ 3□ 2□ 1□
Eğitim, meslektaşlarımla paylaşabileceğim yeni mesleki bilgi ve beceriler kazandırdı.	5 □ 4□ 3□ 2□ 1□
Eğitim, konuya olan ilgimi arttırdı.	5 □ 4□ 3□ 2□ 1□

C. Eğitimi genel olarak nasıl değerlendirirsiniz?
___Mükemmel ___ Çok İyi ___İyi __Orta ___ Zayıf
D. Eğitimin çıktısını 1 kelime ile tanımlar mısınız?
Görüş ve Önerileriniz

Appendix 6 Example of Training Data

Training Name	Participant	Correct Number of Pre-Test	Correct Number of Post-Test	End-of-Training Attainments	General Training Evaluation	Training Output	Age	Age Group	Graduation	Experience	Experience Group
Kaizen Word Game	1	8	10	5,00	5	Kaizen	32	15-20	Associate Degree	15	30-40
Kaizen Word Game	2	4	9	5,00	5		34	0-50	Secondary School	2	30-40
Kaizen Word Game	3	8	9	5,00	5		35	5-10	High School	9	30-40
Kaizen Word Game	4	7	8	5,00	5	Fun and Educational	36	5-10	High School	6	30-40
Kaizen Word Game	5	5	6	5,00	5		36	10-15	High School	12	30-40
Kaizen Word Game	6	7	10	5,00	5		34	10-15	High School	11	30-40
Kaizen Word Game	7	6	8	4,00	4		45	20-25	Secondary School	22	40-50
Kaizen Word Game	8	6	8	4,57	4		38	15-20	High School	15	30-40
Kaizen Word Game	9	9	10	5,00	5	Fun and Educational	31	5-10	Associate Degree	7	30-40
Kaizen Word Game	10	6	9	5,00	5	Fun and Educational	32	5-10	High School	9	30-40
Kaizen Word Game	11	3	10	5,00	5	Fun and Educational	27	0-5	High School	2	20-30
Kaizen Word Game	12	6	10	5,00	5	Teamwork	34	10-15	High School	12	30-40
Kaizen Word Game	13	9	10	5,00	5	Fun and Educational	36	0-50	High School	2	30-40
Kaizen Word Game	14	8	10	5,00	5	Fun and Educational	34	10-15	High School	12	30-40
Kaizen Word Game	15	3	9	5,00	5		29	5-10	High School	5	20-30
Kaizen Word Game	16	5	7	5,00	4		30	0-5	High School	3	20-30
Kaizen Word Game	17	8	10	3,00	3	Educational and Instructional	33	5-10	High School	7	30-40
Kaizen Word Game	18	8	8	4,86	4		46	20-25	High School	22	40-50
Kaizen Word Game	19	7	10	5,00	5	Fun and Educational	38	15-20	High School	15	30-40
Kaizen Word Game	20	8	10	5,00	5	Fun and Educational	26	0-5	High School	2	20-30
Kaizen Word Game	21	8	10	5,00	5	Fun and Educational	31	5-10	High School	5	30-40
Kaizen Word Game	22	3	10	5,00	5	Kaizen	48	0-5	Primary School	3	40-50
Kaizen Word Game	23	9	10	5,00	4	Teamwork	36	0-5	Associate Degree	1	30-40
Kaizen Word Game	24	8	9	4,29	4	Kaizen	39	0-50	High School	4	30-40
Kaizen Word Game	25	9	9	4,29	4	Fun and Educational	31	5-10	High School	7	30-40

Appendix 7 Example of KPI Data

Data Collection Form															
Team Name:Kaizen															
	Section 1					**Section 2**					**Section 3**				
Team Members Name	A	B	C	D	**Card Colour**	A	B	C	D	**Card Colour**	B	A	C	D	**Card Colour**
Pass	1	5				2		1							
Error			1												
1	13,41				Green	7,88				Green	6,88				Green
2			6,56		Red		12			Green		11			Green
3				16,84	Green			9,5		Red			7,5		Green
4			18,01		Green				10,57	Red				8,4	Green
5				19,26	Red	8,72				Green	6,3				Green
6	36,73				Green		10,51			Orange		5,5			Red
7				14,46	Red			4,72		Red			7,4		Green
8	17,97				Green				16,72	Red				6,56	Red
9		9,68			Red		32,2			Green	10,2				Green
10			28,28		Red				20,07	Red		2,2			Green
11				28,34	Green	9,11				Green			6,4		Orange
12	38,89				Red		8,39			Red				8,97	Orange
13								32,08		Orange	7,3				Red
14									20,63	Orange		5,34			Red
15							26,3			Orange					
16								20,83		Orange					
17									12,8	Orange					
18						6,53				Green					
Completation Time(sec)	248,43					269,56					99,95				
Orange Card*30 (sec)	0					180					60				
Net Completation Time(sec)	248,43					89,56					39,95				