UNIVERSITETET I AGDER

Serious Games in Higher Education - The Design Process of a Lean Serious Game

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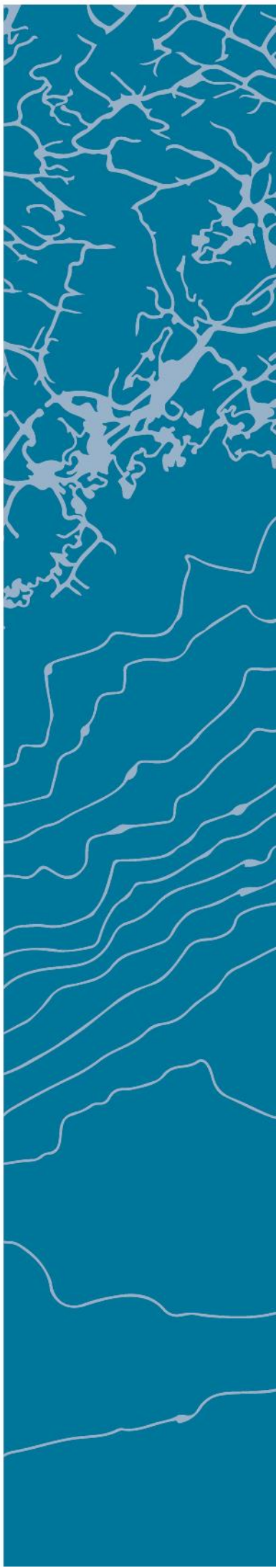

ABSTRACT

As Lean philosophy has increased in interest among business practitioners, policy makers and theorist, developing new ways for teaching lean have attracted increasing interest among universities in order to support their students with the needed skills for their future jobs. Serious games (SGs) have the ability to embody the Lean philosophy through the unlimited opportunities they provide for practicing in a safe virtual world and providing an immediate feedback. Serious games have become an essential future e-learning trend and a well-known term in academic literature. Yet, maintaining the balance between the transfer of knowledge and the playful part in a serious game makes the process of designing a serious game more complicated and challenging.

The topic of this thesis is serious games as a tool to learn some principles of Lean production system, represented by designing a Lean serious game (Lean SG), a web-based serious game developed for learning lean line balancing. There are several studies that stresses the positive impact of serious games as a game-based learning tool, but there are few studies on Lean serious games, and fewer known studies on web-based serious games with an emphasis on Lean line balancing. This research resulted in a serious game for enhancing educators understanding of lean production system by the use of DSR as a research methodology. The constructed lean serious game was built upon recognized pedagogical and SG development principles in an attempt to hold the balance between learning and fun. The research has emphasized the iterative nature of the design process by developing a design cycle which consists of goals identification, requirements analysis, conception and quality check, production and testing phases. The evaluation phase has resulted in emphasizing and highlighting the role of certain factors in increasing SG effectiveness such as ease of use, adaptability and balancing challenge with skills. and insisted in testing as the essence of game development.

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This thesis presents an approach in the development of a Lean training game, where several lean concepts and tools are adopted into a digital serious game. The idea behind choosing this subject was first presented to me by Knut Erik Bonnier, the project leader of the DIKU-financed project "Serious games in higher education" that runs at the university of Agder.

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Fatma Y. M Alrifi

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Abbreviations

CEO= Chief Executive Officer.

DIKU = Direktoratet for internasjonalisering og kvalitetsutvikling i høgare utdanning.

DSR = Design Science Research

DPE = Design, Play, and Experience

FVT = Function verification testing

HCI = Human-Computer Interaction

ICT = Information and communications technology

JIT = Just in Time

MDA = Mechanics, Dynamics and Aesthetics

MDA = Mechanics, Dynamics and Aesthetics

OEE = Overall Equipment Efficiency

SeGUE = Serious Game Usability Evaluator

SMED = System of Single Minute Exchange of Die

SDI = Step-deductive inductive method

SG = Serious Games

SDI = Step-deductive inductive method

TPS = Toyota Production System

UI = Usability Testing in user Interface

UiA = Universiteit I Agder

VSM = Value Stream Mapping-

WIP = Work In Process

WS = Workstation

1. Introduction

Today's global market is characterized by being complex, dynamic and competitive. Technology provides new opportunities, facilitates value creation and takes businesses into the future in a "survival of the fittest" globalized world. In an attempt to enhance and accelerate their graduates' integration in the organizations, and increase their opportunities in the job market, universities have always been seeking for new trends of innovative learning methods. The main aim is connecting student's knowledge with an authentic, and informal contextual learning that involves students actively in addressing real world problems (Rooney, 2012). The selection of training methodologies is influenced by the requirements of the students and the training program targets. This applies to lean training where game is a method used to demonstrate lean concepts and tools. According to Bicheno (2009), games have not the ability to comprehend the full scope of lean but provide players the ability to experience Lean tools and boost some fundamental requirements for a successful lean implementation such as discussion, participation and decision making, something traditional learning methods fail to achieve.

Over time, Serious games (SG) has turned into a trend, using technology to create playful learning experiences. The last years has witnessed an increasingly recognition of Serious game's value and their significantly impact on all levels of education (Johnson et al., 2016). The design of serious games has got more attention due to the fact that many issues in designing and developing serious games are still not adequately addressed. Many studies have been conducted on what makes serious games effective learning tool. (Calderón & Ruiz, 2015; de Freitas, 2018; de Freitas & Ketelhut, 2014; All et al., 2015; Ravyse et al., 2017). Several experts emphasized the importance of one or more of the following factors for SGs effectiveness : learning-game integration, gameplay, interaction, enjoyment, scenario, immersion, narration, feedback, and game design (e.g., Dobrovsky et al. 2019; Khan & Webster, 2017; Marsh, 2011; Muratet et al., 2009). Hersh and Leporini (2018) assume that more research is required for determining the features that play a major role in forming SG learning effectiveness, while Ravyse and colleagues (2017) highlight the importance of conducting researches to lighten the current debates about the role of certain factors in increasing SG effectiveness. As the non-entertainment objectives of learning are added to the design process of serious games, most researchers highlight that achieving a balance between gameplay and learning is vital for SGs effectiveness. (de Freitas, 2007; Seeney & Routledge,

2009). Theories of engagement, motivation, flow and immersion forms the ground for game design literature (Hoffman & Nadelson, 2010).

1.1 Research Question

The aim of this research is to design a serious game for teaching/ learning lean management. as the author has a pragmatic knowledge interest. The game is designed to provide an interactive experience for players where their Lean knowledge is used actively rather than passively. The intention is to let players interact with an authentic environment that describes the core idea of Lean as a tool for improvement. This research aims to answer the following research question:

"How to design a serious game that illustrates some of the main lean production concepts in a way that tries to balance pedagogy with gameplay?"

The intended serious game will be named "The Lean SG" and developed through a design science research (DSR). In this thesis, the process of designing, developing, testing, and evaluation of a prototype implementation will be reported and discussed. It is planned to review the literatures on Lean manufacturing, serious games, instructional design, cognitive and educational psychology and game design. The purpose of this literature review is to underpin the design strategy of this research with the required theories in order to increase the effectiveness of the Lean SG.

This thesis will be highlighting the factors that play major roles in forming serious game's learning effectiveness and satisfying the balance between learning and fun. The designed game will be tested and evaluated in order to control the role of the stated factors in increasing SG effectiveness and to highlight the role of other factors.

In the following, in Chapter 2 the key concepts and the theorical aspects associated to serious games and lean manufacturing are discussed. Furthermore, in Chapter 3, I explain the used Methodological Framework where the research objectives, method and particularly the implementation plan of DSR method to construct the Lean SG are discussed. Then, in Chapter 4, the discussion chapter is presented. It includes the discussion and implementation of the design cycle of the DSR method part and a part that describes the synthesis in the context of the literature. Here it is also pointed to thesis contributions to the literature. Finally, in Chapter 5, I conclude by summarizing the thesis, pointing out the important findings, limitations and suggesting directions for future research in the field.

2. Key Concepts and Theoretical Aspects

Many striking examples of highly motivating activities are introduced in computer games which illustrate many ways to use the unique capabilities of computers in creating motivating environments (Winn, 2008). This type of games adopts familiar game genres such as role play games where learning content is integrated into the structure of the game. Designers of such games motivate active problem-solving and support context-specific learning objectives by letting players explore the space of the game and employ their knowledge to satisfy game challenges. Winn and Heeter (2006) have realized three perspectives on designing serious games: the academic theory perspective that looks from the educational pedagogy; the content perspective that looks into the given subject matter; and the game design perspective which focusses on creating engaging and entertaining game play. In order to obtain the hypothetical potential of games to promote advanced forms of learning, the designer of the Lean SG tried to create a good convergence of content, theory, and game design. This chapter tries to cover and make a theorical base for those three perspectives for the purpose of the Lean SG. The chapter starts with discussing Serious Games and the Challenges facing game designers going through some theorical foundations of game play and game's usability testing. Then lean manufacturing and some of its main tools and concepts are presented.

2.1 Theorical Background of Serious Games

Over the years, researchers espoused the belief that experience has an essential role in learning process developing several pedagogical approaches like problem-based and situated learning. (Boud, 1998). Beard and Wilson (2002) stated that experience is the base of all learning as it gives students a chance to practice in a real-life environment. In formal education, internships and field trips are some popular examples in using experience in learning. Kolb (1984, p. 41) defines Experimental learning as "the process whereby knowledge is created through the transformation of experience." By his theorical model, Kolb emphasizes the continuous and cyclic nature of learning and the importance of experience in learnings process stating that learning is derived from experience. Experiential learning underlines the importance of creating a safe environment where students can learn from their mistakes, something that serious games covers while delivering further learning opportunities (Beard & Wilson, 2002). Particularly in this research, the learning process in the lean serious game is situated within the experimental learning pedagogical theory (Kolb, 1984).

The application of games to educational domains have attracted the interest of many educators due to games ability to provide new opportunities for a highly motivating, engaging experience in addition to a valuable learning experience. Looking at the connection between entertainment and learning, Rose and Nicholl (1998) concluded in their research: "In simple terms a brain enjoying itself is functioning more efficiently."… "When we enjoy learning, we learn better". The purpose of this thesis is to design a useful artifact that is accepted by the client. Artifact acceptance and intention to a possible adoption is influenced by artifact's ability to balance between usefulness and enjoyment (David et al., 1992). A meta data analysis concluded with the result that enjoyment and usefulness have strongly significance on brand attitude and intention to use (Baptista et al., 2019). The same analysis highlighted the strong effect of learning opportunities on usefulness. Thus, keeping the balance between enjoyment and learning opportunities is essential to ensure game's effectiveness.

2.1.1 Serious Games

Klabbers (1999) defines a game as "an activity or sport involving skill, knowledge or chance in which you follow fixed rules and try to win against an opponent or solve a puzzle". The focus of traditional games has often been on entertainment and user experience, but currently games can draw the players attentions using fun aspects for other domains like education (Alvarez, 2008). While Prensky (2001) confirms that a game should include the elements of goals, outcomes and feedback, challenge, interaction, rules and story, there are different attempts in defining a game and what elements it should include. Brathwaite and Schreiber (2009) emphasize this idea in their definition of game: "An activity with rules. It is a form of play often but not always involving conflict, either with other players, with the game system itself or with randomness/fate/luck".

More interesting for this study, is de Freitas (2006) definition of digital game-based learning: "applications using the characteristics of video and computer games to create engaging and immersive learning experiences for delivering specified learning goals, outcomes and experiences". In an educational context, game is a goal-oriented and rule-bounded play format that has the objective of enhancing the effectiveness of students' learning (Bellotti et al., 2014). This approach has got the term "Serious games" and was introduced for the first time by Clark Abt in "Serious Games" book published in 1970. Clarck wrote in his book:" We are concerned with serious games in the sense of that these games have an explicit and carefully thought–out educational purpose and are not intended to be primarily for amusement". In this book, the notion was employed for card games with educational

objectives. Currently, it is widely acknowledged that the concept is applicable in a computing context and is not limited to video games but features also educational games. Zyda (2005) defines serious game as "A mental contest, played with a computer in accordance with specific rules, that uses entertainment to further govern or corporate training, education, health, public policy, and strategic communication objectives".

2.1.2 Challenges in developing Serious Games

Over recent years, a growing body of literature has emphasised the increasingly significant role serious games have across a range of educational contexts. After his math game, Harris (2008) concluded that a goal-oriented gameplay had boosted team interactions among students. Another example is "ASTRA EAGLE" serious game, that showed improved performance among groups playing the game compared to non-gaming groups. Another study made by Annetta et al. (2009), inspected the use of serious games on learning outcomes of genetics and emphasized its effectiveness. However, developing an effective serious game is not that easy. The optimization of the potential for experiential learning in serious games is very hard and challenging. The reason lies back the difficulty in developing an "authentic" learning environment that replicates a real-world experience and that gives students the chance to participate in situations that may be inaccessible in the real life (Barab et al., 2000).

Another challenge is keeping the balance between challenge and simplicity. The cognitive overload is undesirable in serious games and the simplicity is required for more learning and engaging game (Kiili, 2007). The meta-analysis conducted by Baptista and colleagues (2019) emphasizes the strong impact of ease of use on enjoyment. At the same time, the game should keep a suitable level of challenge for the learners (Csikszentmihalyi, 1990) as many studies stressed that lack of challenge is a typical reason for disengagement (Shernoff, 2010;2013). Furthermore, to make a game entertaining and engage players, games should be pleasantly frustrating, challenging without being boring or unmanageable (J. P. Gee, 2007), (Girard et al., 2013). In computer learning environments, boring content has negative impacts on learning and problem behaviour (Baker, 2010). Obtaining this balance between challenge and simplicity; challenge and boredom is too far from simple.

Another challenge results from the difficulty of attaining a balance between gameplay and pedagogy that is considered as the key of an effective serious game. Newbery (2016) states that Serious games are those that are not developed for entertainment purposes but exclusively for educational purposes. Designers Michael and Chen (2006) underline the

significance of education in serious games in their definition: “a serious game is a game in which education (in its various forms) is the primary goal, rather than entertainment”. Zyda (2005) states that pedagogy is the element that differentiate a serious game form a video game that consists of story, art, and software. While pedagogy is vital for considering serious games as a learning tool, equally important is the attainment of player engagement. Zyda (2005) stressed "pedagogy must be subordinated to the scenario of the game" to emphasize the importance of strengthening the compromise between playfulness and educational aspect in a serious game.

2.1.3 Design Process of Serious Games

Winn (2008) emphasizes the difficulty of creating a good serious game insisting that it is much harder than making a normal game. He assumed that the reason lies back that a serious game has to be optimized to obtain a set of learning outcomes in addition to the focus on the entertainment aspect. This gives the design process more importance in serious games.

Reiner Knizia, the board game designer says, “I don’t have a fixed design process. Quite the contrary, I believe that starting from the same beginning will frequently lead to the same end. Finding new ways of working often leads to innovative designs.”. However, many views with slight differences have been developed on serious games design. Researches like, Marfisi-Schottman et al. (2009), Annetta (2010), Van Eck, (2006) have many common elements that have the objective of combining the learning, design and gameplay in order to make an effective serious game.

While White(1998) identifies design as “ a creative, iterative, decision making process.”, goes Simon (1996) to describe it as a generator-test cycle: “ think of the design process as involving, first, the generation of alternatives and then, the testing of those alternatives against a whole array of requirements and constrains”. Figure (2.1) shows the model developed by Marfisi-Schottman et al. (2009) that provides a vision of a chain for serious games production that includes a detailed description of the different phases of the design process for serious games. This design methodology is inspired by industrial engineering theories and has quality control as a basis to determine serious game’s ability to confront to client’s needs by comparing the game in the design process with the initial specifications. In this way, those quality controls help in avoiding problems and rework by fixing any problems in the early phases of the design process.

Figure (2.1): The serious game production chain (Marfisi-Schottman et al.,2009).

However, this model was criticized by researchers due to the fact that the design process is an iterative process, something that is not addressed in this model (Marne et al., 2012). Therefor this model will be partly used in this thesis and it will be combined with the generate-test cycle developed by Simon (1996) to avoid this limitation. The generated model will be discussed in detail in the method chapter.

In order to be effective, the design of the user interface of serious games should be simple with no need for explanations. The main focus of users should only be the content of the game. For this purpose, Benyon, Turner & Turner (2005) have extended the following list of user interface principles that will be used while designing the Lean SG.

Benyon, Turner & Turner (2005) list of user interface principles

- Visibility: All functions in the system should be visible to the user
- Consistency: Actions in the system should have similar sequences in similar situations
- Familiarity: The symbols and languages used in the system should be familiar to the user
- Affordance: Pattern of the design should be clear to the user (for example, switches should look like switches that can be turned on or off)
- Navigation: The users can navigate easily between the different parts in the system
- Control: The users have control on the system
- Feedback: The system should shows respond when the users make action
- Recovery: The system should have the ability to redo an action and the errors can be recovered.
- Constraints: To avoid errors, the system should have constraints
- Flexibility: The system should have the ability to customize its properties to meet the user behaviour.
- Style: The style of the system should be attractive to the users
- Conviviality: The system should appear friendly to the users.

Figure (2.2): List of user Interface principles (Beynon et al., 2005).

2.1.4 What makes a serious game a game?

In game design, game play is the most pivotal feature (Kiili, 2005). A game is not just a set of pedagogical objectives, but a place where those goals are linked to game elements to combine learning with fun. Winn (2008) emphasized that gameplay has impact on the motivation of players. A good gameplay motivates players to continue playing and make the most of the intended goals. Adding the game elements to the pedagogical objectives occurs in the phase where the overall scenario of the game is created. Marfisi-Schottman et al. (2010) describes this phase writing: "The storyboard writer and the artistic director need to work together to structure the pedagogical scenario and match it up with a fun scenario. They mainly have to describe the elements of the virtual environment such as the storyline, the characters and the different places where the action will take place".

In order to make it easy for developers, scholars and researchers to design a broad class of game artifacts, many frameworks have been built. The MDA framework was one of the first and the most fundamental approaches to game design that was widely accepted in academia (Hunicke et al., 2004). Mechanics, Dynamics and Aesthetics aspects were identified in this approach. The Mechanics aspect goes to explain the components of the game related to algorithms and data representation while the Dynamics explains mechanics run-time behaviour on players input and output. The Aesthetics part describes how player's emotional reaction should be while interacting with the game. However, the approach was criticized for several limitations like focusing too much on mechanics something that makes MDA not suitable for any type of experience-oriented design. (Duarte, 2015), (Polansky, 2015), (Lantz, 2015). Winn comments that MDA "does not specifically address aspects of game design beyond the gameplay, including the storytelling, user experience, and influence of technology on the design" (Winn, 2008).

Other frameworks were built to overcome those weaknesses in MDA framework such as the Motivation Design process (Werbach, & Hunter, 2012), the Player Cantered Design methodology (Kumar, & Herger, 2013), and the Octalysis gamification framework (Chou, 2014). Winn (2008) introduced the Design, Play, and Experience (DPE) framework by expanding MDA to be more suitable for Serious games (see Figure 2.3). DPE takes into account that serious games include in addition to gameplay, educational content to be taught; settings, characters and narratives that makes a story to be introduced; a user interface to be viewed and an underlying technology to be used. This framework stresses that prototyping and play testing are important phases due to the fact that the designer doesn't have direct

control over player's perceived experience while playing the game. Therefore, DPE framework provides a logical distinction of the elements that should be concluded in a Serious Game dividing them into learning, storytelling, gameplay and user experience subcomponents.

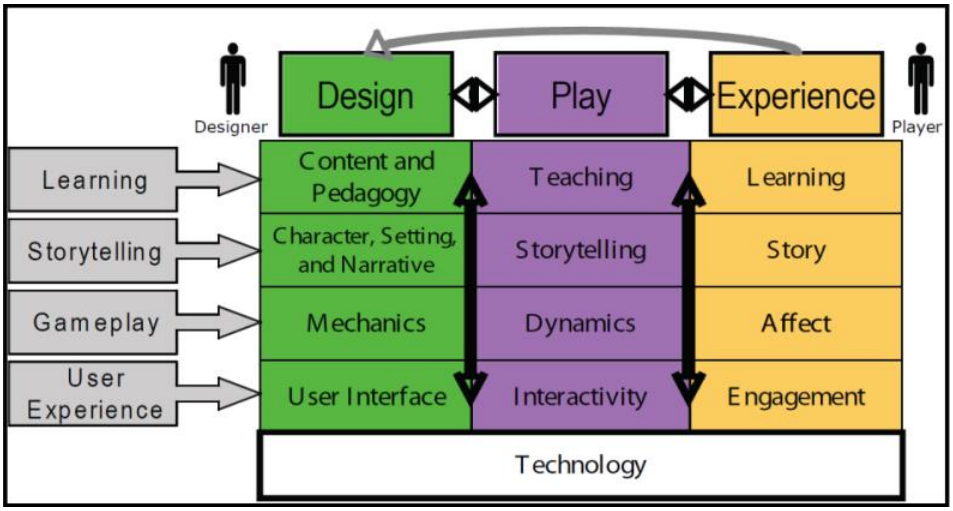


Figure (2.3): DPE Framework from Winn (2008).

Fullerton (2014) identifies basically the same elements of game design as in the DPE model but he provides more in-depth explanation of those elements. Fullerton distinguishes the elements into formal elements, systems dynamics elements and dramatic Elements According to (Fullerton,2014), a game can be defined by 7-formal elements, these elements are: Players, Objectives, Procedures, Rules, Resources, Conflict and Outcome. Those elements are described in the following table.

Table (2.1): The formal elements of Fullerton (2014).

The formal elements	
Players	This element defines the number of the players and their rules in the game and how do players interact with the game. The number of the players in a serious game depends on the capability that needs to be taught.
Objectives	This element defines the reason for playing the game. Many games have one main goal to achieve, however a serious game can have multiple sub-goals in order to reach the main goal. The objectives of a serious game create the challenges and the fun to achieve the main goal which is in this case learning issue. The goals of the game should be clearly defined, challenging, achievable and fit to the pedagogical purpose of the game.
Procedures	The objectives element should be excused through methods and actions that the players can undertake. A serious game has different type of actions and methods that have to be realistic in order for players to learn something they can use in their daily organization work.
Rules	This element defines how the game can be played. These rules consist of the restrictors and boundaries of each action in the game that the player must follow to achieve the objectives and the goals of the game.

Resources	This element defines the resources that the players must use wisely to reach the goal of the game (Example of these resources could be time, currency, units and health). In order to make the game more realistic, these resources must be scarcity and useful. Useful means that the player will learn and experience by playing, while scarcity means that the player face challenges in order to achieve the goals, these challenges force the players to think before taking any decision.
Conflict	This element defines the obstacles that prevent the players from achieving their goals directly, an example of these obstacles are the conflicting interests within the organization. The conflict in the serious game should be balanced so that it is not too easy leading to boredom or too hard leading to that players are not able to continue the game.
Outcome	This element defines the final state of the game which is not clear at the start phase. In the serious game a training and a learning is the outcome, which will be in the form of points and indicators. These points must vary each time playing the game which means that the outcomes are varying from player to player and from time to time, and the players should receive feedback in order to make the game a learning tool.

Systems elements explains how the different objects in the game is interacting. Fullerton (2014) divides system element into objects, properties, behaviour and relationships. In order to make the game dramatic, the designer should add challenges to their games in order to encourage players to continue playing without getting bored. These challenges engage player who will all the time look forward knowing how the end will look like. According to Winn (2008), dramatic elements includes characters, setting and narrative. Systems and Dramatic elements are explained in table (2.2)

Table (2.2): The system dynamics and the Dramatic elements by Fullerton (2014).

The systems dynamics Elements	Dramatic Elements
-Objects element: This element includes every single object in the game that interrelates to each other making the system. It can be the player, a concept or a piece of the game. Those interrelations among objects should be clear for the player and be as near to the real world as possible. **-Prosperities element:** This element describes the attributes that the physical and conceptual aspects have. Each object has defined properties that gives it the ability to make certain things. It should be clear for players which actions they can do. **-Behaviour element: T**his element describes the actions that an object has the ability to make. Jumping, shooting, communicating, choosing are some examples of behaviours. The players should get a feedback on their behaviours so that players can see the impact of their actions. -**Relationships**: This element describes the relationships between objects. In serious	**-Characters:** This element describes games ability to immerse players into their characters in the game. Four layers are defined by Isbister (2006) to enhance character immersion and forms player's experience. These are Visceral Feedback, Cognitive Immersion, Social Affordances and Fantasy Affordances. Visceral Feedback is the emotional feedback players get from an action that makes them want to do it again. While cognitive Immersion is about giving players the freedom of choice between actions and the possibility to plan several actions. Social Affordances includes the correlative interactions between a system, its users, and the social context. The player should be immerged into the social setting that he/she got in the game. Fantasy Affordances means how the player interacts with the fiction elements in the game. The game should provide players a place where they can explore their desires without fearing in a safe environment. **-Settings:** In order to make player's experience richer and place him/her into a perspective, the choice of a suitable setting is essential. This choice can be based on the story of the game. The characters and the narrative of the game can be built basing on the setting. **-Narrative:** In order to give players a context and engage them into playing learning activities that the game provide, it is good with a background story. The player should understand what they are involved in and what they are doing in the game by

games, fundamental relationships should be visible. This enrich the learning experience as it reflects how the reality looks like	providing a narrative. The game should engage players to a narrative and then provide them the chance to alter the narrative (Dickey, 2005). Rooney (2012, p 52) states "The game serves as a frame for a story that is co-authored by the interaction of the player and the game".

2.1.5 Relating Engagement, Flow, Immersion, and Motivation theories to SG Development

As discussed before, although serious games have the primary purpose of educating or training, they are also designed to provide entertainment and leisure (Davidson, 2008). It is commonly believed that the psychological factors of engagement, flow, immersion and motivation are the characteristic to an effective game and a learning experience (Hamari et al.,2016). The ability a game has to create engagement is essential for making it entertaining. This power of engagement has inspired many students to investigate their opportunities of learning (Kiili, 2005; Van Eck, 2007; Whitton, 2009). Engagement is defined by Benyon and colleagues (2005): "Engagement is concerned with all the qualities of an experience that really pull people in – whether this is a sense of immersion that one feels when reading a good book, or a challenge one feels when playing a good game, or the fascinating unfolding of a radio drama.". Three types of engagement have been identified recently: the behavioural, cognitive and emotional (Paris et al., 2004) which should be correlated in a game-based learning environment (Pellas, 2014). Hamari and Koivisto (2015) confirm that a system should have the right amount of hedonic dimensions (excitement, fun and pleasure) in order to influence customer engagement.

Games offer a mode of interactivity where human- computer interactions take place providing the experience of self-efficacy and flow that motivate and engage players (Breuer & Bente, 2010). Flow experience is essential for engagement, it is defined by Harper and Row (1990) as "the state in which people, are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost, for the sheer sake of doing it". Crisp (2014) assumes that game-based learning becomes a method to invoke engagement and flow in students. According to the flow theory introduced by Csikszentmihalyi (1990), the main two elements of flow are challenge and skills. Those elements are speculated to anticipate engagement which on its part is believed to anticipate perceived learning. In serious games, the focused concentration required by intrinsically interesting and challenging activities are often combined with the pleasure perceived while maximally utilizing player's skills (Csikszentmihalyi & Schneider, 2000). Thus, the main

condition for flow experience to occur is driving players to use high level of skills to satisfy a significant challenge in order to avoid apathy, relaxation, or anxiety (Strati et al., 2012). There is a considerable disagreement among researchers about the relationship between immersion in the game and learning. Thompson et al. (2012) stated that the nature of immersion that characterizes flow experience has relationship to learning and related emotions. According to Cheng, She, and Annetta (2015), the immersion has a positive effect on learning, this is the case especially when players have high gaming skills. However, the results of a study made by Hamari et al. (2016) showed that immersion in the game has no significant effect on learning. Furthermore, the same study showed that the challenge and skills have a positive impact on being engaged and immersed in the game.

Fullagar, Knight, and Sovern (2013) found that challenge-skill dynamic has also influence on increasing motivation by extending players' capacities. Prensky (2002) considers the motivation of gameplay as the REAL 21st century learning revolution. Motivation is related to cognitive engagement in learning as it helps in maintaining learner's attention focused. This moves us to another base of game design that is 'the theory of motivation' defined as "an internal state that arouses us to action, pushes us in particular directions, and keeps us engaged in certain activities" (Ormrod, 1999, p. 407). Motivation is considered as an essential determinant and driver of student learning. The theory differentiates between two types of motivation, **the intrinsic motivation** where the source of motivation lies intern within the student and the mission and **the extrinsic motivation** where the source of motivation is external to the student and the mission. Researchers stressed that the intrinsic motivation is much powerful than the other type since intrinsically motivated students show more enthusiasm and creatively perform their tasks learning from their failures and looking for improvement (Ormrod, 1999). Challenge, fantasy, and curiosity are three of the major kinds of motivation synthesized by Piaget(1951) who states that the will drives players to mastery (challenge) to pursue optimally informative environments (curiosity) which is partly absorbed by the use of schemas from other contexts (fantasy). Groen (1978) criticises Piaget's theory of being too ambiguous or extremely general. Basing on Piaget's work, Malone (1987) introduced a framework for a theory of intrinsically motivating instruction diving into those three elements. He had also added collaboration and competition element which emerge only in games involving more than one person.

Several researches aimed to clarify and determine the key game features that produce engagement, motivation, immersion and flow in serious games. Based on flow theory,

Whitton (2009) described eight elements that should be present in a game in order to make it more engaging, enjoyable and immersive, the elements are shown in figure (2.3). Many other researches present more or less the same features but with slightly differences. Figure (2.3) illustrates also the features introduced by Bowman (1982) and Malone (2001).

Table (2.3): Game features that identify player engagement.

Whitton (2009)	Malone (2001)	Bowman (1982)
1. A challenge that requires skills with an attainable goal and known rules; 2. Complete absorption in the activity; 3.Clear goals; 4. Immediate feedback; 5. Concentration on the task in hand; 6. A sense of control; 7. loss of self-consciousness; 8. Transformation of time.	1.Challenge (goals with uncertain outcomes); 2. Fantasy (narrative, pleasurable and imaginary content); 3. Curiosity (sensor curiosity through graphics and sound, and cognitive curiosity where the player should solve something unsolved) 4. Collaboration and competition	1.Clear task, identifiable roles and responsibilities, 2.player choice; 3.balance between player skills and challenges

2.1.6 Usability Testing in Serious Games

Usability testing is "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (ISO 9241-11, 1998, p2). Extensive research has attempted to shed light on the significance of usability testing in user interface (UI) design and human-computer interaction (HCI) fields. (Moreno-Ger, 2012) (Ackerman, 2005). Identifying design issues that can avoid users' engagement and interaction with innovative applications has gained an increasingly focus among product designers. Serious games differ from other software productivity tools in their ability to engage users providing them a road for knowledge discovery. Usability testing for serious games is especially important due to the fact that SGs often target a broad heterogeneous audience that may include individuals that are not used to play games. The adaption of game usability evaluation methodology is essential to shed light on any problem that can interrupt the game's educational mission and to ensure that users will be able to interact adequately with the game having a pleasantly frustrating exploratory experience. There is a common agreement among researchers about the importance of evaluating system related and user related dimensions including the aspects of learning effectiveness, engagement, and the fitness of Serious Game's design and target population (Freitas.

Oliver,2006). The nature of usability as a relative concept that depends on the user, the task, and the environment makes the process of measuring usability a difficult one. Although several heuristic instruments of usability measurement have been developed by experts in the SGs field, the process is still not that simple since these instruments have not always the ability to identify all the obstacles in a design (Kessner,2001) (Nilsen. M. E, 1994). Macleodand and Rengger (1993) have categorized the methods used to evaluate usability as

1. Expert methods where usability issues are identified by specialized evaluators.
2. Theorical methods where usability issues are predicted basing on theorical models.
3. User methods where usability issues are identified by giving the prototype to users to interact.

One common approach of usability user methods is the observational analysis in which evaluators observe users while interacting with the prototype and note all pitfalls and design failures. The survey-based methods are another approach based on surveys in which end users replay to a questionnaire right after testing the game. Observational user methods are used when there is a need for observing end users while interacting with the system to be able to identify specific issues (Macleod. Rengger, 1993).

Fullerton (2014) states that play test sessions should be structured to be able to get the most benefit from them. As exploring useful existing tools helps the designer to create the game in shorter time (Fullerton, 2014), the Serious Game Usability Evaluator (SeGUE) developed by Moreno-Ger and colleagues (2012) is used under this research. For annotation purposes, (SeGUE) identifies several terms for each of the two dimensions (the system related and the user related) presented in table (2.4).

Table (2.4): The dimensions of Serious Game Usability Evaluator by Fullerton (2014).

Event categories for the system dimension	Event categories for the user dimension
- Functionality: This event occurs when a control item fails to make what it is supposed to do. - Game flow: This event is related to the game sequences interaction and output and not to a specific interaction. - Content: This event is related to the game's textual information. - Layout: This event is related to how the user react to the different layout elements. Negative when the user is confused about how to use the different controls and positive when the user likes the design	- Learning: the player learns how to use the system after considering it as unclear (learn to play). - Reflecting: The player pauses in order to make an action plans within the game space. - Excited: The user expresses his feelings with positive reactions. - Pleasantly frustrated: The player displays frustration in a positive way that reflects that he insists to overcome the challenge. - Frustrated: the player expresses frustration in a negative manner that reflects that he is not able to continue the task.

- Technical error: This event related to unexpected error that must be corrected. - Nonapplicable: This includes events that do not belong to the system.	- Confused: the player is not sure what he is supposed to do. - Annoyed: the player feels badly about having to accomplish a task in the game. - Unable to continue (fatal): the player has not the ability to continue playing as a result of the above events or a fatal technical error. - Nonapplicable: the event is not related to the player. -Suggestion/comment: when the player comes with a comment that has not any relation to the event. -Others: other events that is related to players but not defined above.

2.2 Lean Production System

The need of meeting the challenges of the global competitive market, made it inevitable for companies to use new philosophies and techniques in order to increase the productivity and customer satisfaction. Over the last decades, lean manufacturing has widely been executed and more and more companies are seeking for a fully lean implementation. Consequently, it is desirable that graduated students have a good understanding of lean manufacturing so that they can replicate their learning experience in the companies they work in. Many attempts are made to introduce more student-active learning methods that support this objective. The Lean SG designed in this thesis has the goal of innovating and strengthening students' learning and competence in lean manufacturing. This section presents the lean theorical base that underpins the lean serious game, going through all lean concepts, techniques and methods to be used in the lean game.

Toyota Production System (TPS) is the base of lean manufacturing (Stewart & Raman, 2007). The Toyoda family is the one that designed lean (Wig, 2014, p48). Developing lean was a long and detailed process influenced by many circumstances such as the Japanese economy, new government restrictions, and other coincidences (Womack & Jones, 2007). The foundation of the lean idea was finalized in the early 1960s. Lean was quickly incorporated into other Japanese car companies (Womack & Jones, 2007). The word lean was first used during a research project at MIT in 1998 by John Krafcik. The result was published in 1990 in the book, "The Machine that Changed the World" by Womack and Jones. Their publication addressed the concept of lean and elaborated on it (Modig & Åhlström, 2012).

Lean manufacturing is an organizational model that is intended to waste elimination and value creation (Womack et al.,1990). Many organizations consider lean as a tool to boost performance, increase productivity and improve processes by involving the implementation of lean in their short and long goals and strategies. Tackling and embracing Lean tools are not the hardest part of lean implementation as creating a lean culture and changing habits and belief systems require a lot of time and hard work. As employee involvement is vital for a successful lean implementation, organizations support learning at the organizational and individual levels. It includes getting all employees to embrace lean, question everything they do and work continuously to satisfy customers. There is agreement among authors that lean manufacturing is aimed to satisfy customers' needs by creating products with high quality and without waste throughout the value chain (Womack et al., 1990).

2.2.1 Lean Principles

According to Womack and Jones (1996b), lean manufacturing has some principles that forms its basis: creation of value, dentification of the value stream, continuous production flow, implementation of a pull system and pursuit of perfection.

1. **Value creation**

The company should define what gives the customer value. Not only the most obvious properties, but also properties that were not initially thought to create value for the customer (Womack & Jones, 1996). A well-known example is that car customers do not necessarily require cars to make low noise, but rather that the noise is in a certain pitch (Cooper and Chew 1996). This means that one must be extremely careful in defining customer value in order to produce the right quality, and not waste resources on products the customer does not want. Lean stresses that the focus should be on both internal and external customers. In order to improve the existing products and services, companies should question and examine internal value creation by challenging employees to find creative ways to meet customer needs. (Eakin, 2020). Value creation is about continuous improvement by getting everyone to see and embrace lean and work together to explore waste and act only on fact and not opinion.

2. **The value stream**

A product goes through a specific sequence of activities that adds value to the product from the start to the end where it becomes a finished product. One of the main goals of lean production is to create a value chain that consists only of activities that create direct value for

the customer. To do this, one must first map the value chain, and then categorize activities to what degree they create value or not, and whether they are necessary for further operation. Womack and Jones (1996) describe three types of activities: 1. Value-creating, 2. Non-value-creating but necessary and 3. Non-value-creating and not necessary. Type 3 muda are activities you can and must get rid of right away. Since they are neither necessary nor add value, there is no reason why these should continue to be part of the company's activities. Type 2 muda, on the other hand, is not as easy to deal with. Here you have to have a long-term perspective with the vision of eliminating the type2 muda which requires often system-level changes like upgrading machines / equipment. (Womack and Jones, 1996)

3. Flow Creation

The third principle is to create a flow in production, so that the products flow through the processes with the fewest possible stops and shifts (Eriksen, Fischer &Mønsted 2005). When the products do not stop in production, it means that you do not have to store with waiting products. In addition, the products will go through the production process faster. With fewer shifts of responsibility, this will also minimize the time it takes to move products or people around.

4. Pull system implementation

In a pull system, it is the customer's needs that control the production. This means that customer orders should initiate a process for finalizing the product. In this way, the production of unneeded products that no one is ready to buy is avoided. Production can be based on forecasts, but no buffers should be produced to ensure that customer needs can be met (Aaram, 2003). However, it is not always advantageous to implement pull as it depends on what is being produced as well as the demand as in the process industry. Demand in some markets is so high that production is continuous (e.g. GE Healthcare). (Hopp,2004)

5. Perfection persuasion

The main aim of lean manufacturing is to maintain improved production and always seek perfection (Womack & Jones, 1996). A lean company must constantly strive for the perfect, and the whole culture builds on the idea that one always looks for improvement. Continuous improvement can be seen as a continuous learning process that takes place both at the organizational and individual levels and in some cases across organizations. It is this point that can take a long time to be properly implemented since it requires an organizational

culture that facilitates the mindset. Cultural changes often take a long time, preferably 3-5 years (Bicheno & Holweg, 2016).

2.2.2 Customer Satisfaction as an Important Term in Lean

Kotler defines satisfaction as a person's feeling of joy or disappointment at how he thinks the company's product works in relation to expectations. Great satisfaction will create an emotional bond with the company or brand. Doing a better job of meeting or exceeding customer expectations is the key to win more customers and to help companies to be strong competitors in the market (Kotler 2003). For the purpose of understanding how to achieve customer satisfaction, companies must first know what creates value for the customer in terms of the combination of quality, service and price. Perceived customer value is the potential customer's evaluation of all the goods and all the costs of company's offer compared to other alternatives in the marked. Total customer value is the perceived monetary value of the entire combination of financial, functional and psychological benefits that customers expect from a given offer. Customer's expectations for the product will determine the extent to which the customer is satisfied. (Kotler 2003).

The goal of making customers satisfied is to create customer loyalty, as there are lower costs associated with retaining an existing customer than it is about creating new customers. A business can only win by creating and delivering superior value, which means five skills: Understanding, creating, delivering, capturing and maintaining customer value. To succeed, companies must concentrate on the entire value chain. The key to achieve high customer loyalty is to deliver high customer value and to make the customer happy even after the sale.

Kolter (2003) states that 96% of dissatisfied customers do not complain but just stop buying, this ensure that measuring customer satisfaction is not as simple as counting customer complains. Companies should conduct customer satisfaction surveys, hire people who act as customers who can provide feedback on good and bad experiences, analyse lost customers and make it easier for people to complain. A very satisfied customer is loyal over time, which is advantageous as the company depends on its customer base to create profitability (Kotler 2003).

2.2.3 Waste as a Central Term in Lean

In a multitude of resource areas, including organizations, processes, and systems waste can be found. An enormous amount of "non-value-added" activities that add nothing to the timing, or the quality of the output could easily exist. Waste is seen as a central term in classical Lean literature (Krafcik, 1988). Waste, referred by a Japanese term “muda”, was defined by Ohno (1988) as “anything other than the minimum amount of equipment, materials, parts, and working time essential to production”. In lean production, an activity is considered a nonvalue-adding activity if the customer is not willing to pay for it. As waste causes reduction of profit margins, quality, customer and staff satisfaction driving up consumer costs, it is considered as an integral part of lean. A survey conducted in Sweden shows that 30 - 35% of the production cost in a project can be a result of waste (Josephson &Saukkoriipi, 2005). In the long run, production costs can be halved, as not all waste is identified in the survey (Josephson &Björkman, 2011).

In TPS, seven categories of waste for mass production are identified (Koskela et al., 2013). As other industries adopted the lean philosophy, the list was also used to understand waste in production. In TPS, the following seven categories of waste in production were identified (Ohno ,1988), (Shingo,1989):

Table (2.5): The Seven Wastes.

Type	Description
Overproduction	Overproduction was considered by Ohno as the most serious waste since it is the root for other wastes. Overproduction avoid a smooth flow of products as they are manufactured before it is required or more than what is required. The type of production system called ‘’Just in Case’’ costs a lot of money since these products need to be stored and transported around. To avoid this problem lean production follows a system that is called ‘’Just in Time (JIT)’’ where the product would be manufactured just on demand (Bicheno & Holweg, 2016).
Transporting	Movement of materials between different processes or from one location to another is called transporting. Transporting adds no value to the product but costs money since materials and products that should to be transported needs workers efforts and machines. the number of transports is proportional to the number of defects and deteriorations (Bicheno & Holweg, 2016).
Waiting	Waiting is the enemy of smooth flow. Waiting for a previous step in the process leads to waste. This further creates problems by reducing productivity, and increasing the cost of products (Kulkarni et al., 2014). In order to reduce waiting time in the factory, good organization of production will be a key factor, as this will reduce unnecessary waiting for workers and machines (Modig & Åhlström, 2018). Linking the process together by ensuring better martial flow, minimizing distances between process such that one process feds directly the next one, will reduce waiting (Bicheno & Holweg, 2016).
Defect	A product or service classified as defected if it cannot satisfy customers requirement or specification. In quality costing, two types of defects are identified: the internal (scrap,

	rework, delay) and the external (warranty repairs, field service) defects. A defected products or services lead to huge cost due to reworking, rescheduling and capacity cost. This waste can be reduced by continuous process improvement. Defects that are not detected before they are received by the customer are the worst as they can create distrust between customer and supplier / manufacturer. (Bicheno & Holweg, 2016).
Motion	This waste is related to ergonomics and is seen in all instances of bending, stretching, walking, lifting, and reaching. Motion reduce work efficiency in addition to some health and safety issues, which in today's litigious society are becoming more of a problem for organizations. Cell layout, poorly arranged space, disorganized tools are some reasons of the waste of motion. with Jobs. excessive motion should be analysed and redesigned for improvement with the involvement of plant personnel. (Bicheno & Holweg, 2016).
Over processing	With over processing, you create a product or service that is more advanced than what the customer actually asks for. The reason for this may be that you do not have sufficient control over what the customer is actually demanding or how much is needed (Kulkarni etal., 2014).
Inventory	Inventory is the enemy of quality and productivity. It should contain materials or components necessary to complete the product or work process while Items that are not used in the warehouse become worthless, as these items only take up valuable storage space, which could be used to store more central and important components (Kulkarni et al., 2014). The number of goods in inventory represents restricted capital for the company, and unnecessary goods in inventory can cause extra work for the employees (Modig & Åhlström, 2018).

All the types of waste mentioned above go by the name of the seven deadly wastes (Hicks, 2007). These seven points are easy to see as obstacles to relative success for lean implementation. By eliminating as many of the points as possible, it will be possible to achieve continuous improvement potential, increased productivity, increased quality and better management (Hicks, 2007). Once the points that create waste are identified, it will be possible to use tools that further reinforce the goal of becoming a lean (Hicks, 2007). It is also important to point out that there are two closely related other waste categories that are particularly important in terms of production: Overburdening/muri where you run machines and / or personnel too hard and Underutilization of employees where one does not utilize the expertise of the employees. E.g. that one uses engineers for cleaning.

2.2.4 Waste Reduction Techniques

Lean manufacturing introduced a package of waste reduction techniques as setup time reduction, zero defects and line balancing.

1. **Setup time reduction**

In order to reduce the setup time on machines, Ohno devised the system of Single Minute Exchange of Die (SMED) helped in reducing die changing time too much (Womack, Jones and Ross, 1990). The main goal of this system is to move the internal setup activities (those performed only when machines lies still) to external setup activities (those performed while

the machine is working) wherever possible. (Feld, 2000). This gives companies the ability to have more variety of product mix and producing in small batches something that can reduce the inventory. Furthermore, SMED reduces the costs as it eliminates the need of die-changing specialists. (Feld, 2000).

2. Zero defects

The principle of zero defects includes ensuring that the products produced and improved throughout the manufacturing process are fault free (Karlsson &Ahlstrom 1996). The main goal of this principle is to avoid the appearance of defective parts at the end of the manufacturing process by detecting and preventing errors from happening at the source. For this purpose, Shingo developed the Poka-Yoke tool which is an independent error control system fixtured to a machine that check all parts of the product in order to make sure that the products are fault free avoiding the movement of the defective parts to next workstations (Feld, 2000).

3. Line balancing

Another technique to reduce waste, is line balancing that ensures that a workstation in a production line operates in a synchronized manner with other workstations. The basic idea is regulating each station's volume of work to the right size in order to avoid any stoppage while sending the work from station to another (Mid-America Manufacturing Technology Center Press Release, 2000).

While satisfying the needed output from a line, the imbalance between machines and operators should be minimized. Cycle time is the production rate or the time that a unit of the product needs to be produced. For optimum utilization of work force, companies usually group certain activities to workstations to adjust the cycle time at each workstation to the maximum. Due to the different cycle time at each workstation that causes waiting waste in the line, the line should be balanced. This sequencing implies the allocation of operators and machines to operate activities in different workstations in order to optimal utilize the facilities of the assembly line (Sharma, 2009).

The process of assembly line balancing involves three steps Heizer et al (2000) presented the process of assembly line balancing in three steps:

1. Calculate the cycle time needed to meet the required the production rate:

$$Cycle\ time\ = \frac{Production\ time\ available\ per\ day}{Units\ required\ per\ day}$$

2. Calculate the theoretical minimum number of workstations.

$$Minimum\ Number\ of\ WS = \sum_{i=0}^{n} \frac{\text{Time for task } i}{Cycle\ time}$$

Where n is the number of assembly tasks

3. Balance the line by assigning specific assembly tasks to each workstation.

- **Takt time**

Takt time is the rate of the available work time per shift to meet customer demand and is calculated by the following formula (Rother &Harris, 2008):

$$Takt\ Time = \frac{\text{Available work time per shift}}{\text{Customer order quantity per shift}}$$

In order to meet customer demand, products should be produced within the takt time. For example, if the customer has an order every 8 hours, then the product should be produced within 8 hours.

The formula above is valid when the customer has steady orders, however, if the orders are varying from time to time, then it would be difficult to calculate the takt time. In this case, it will be helpful to gather the information of actual shipment in a specific period and then the takt time can be calculated for the particular product, thus, the production can be balanced to meet changing customer demand.

- **Cycle Time**

According to Rother et al. (2008), Cycle time is the average time that is needed to complete producing a product by a particular process and it is calculated by the following formula:

$$Takt\ Time = \text{processing time} + \text{set up time} + \text{waiting time} + \text{moving time} + \text{inspection time} + \text{rework time} + \text{other delays to complete the job}$$

2.2.5 Lean Tools

According to Womack & Jones (1996), if one can follow the five principles of lean, it is possible to eliminate company's waste to a large extent. To follow these principles, there are a large set of operational tools that can be used to support the principles. For better lean implementation, those tools should be used properly to reduce waste, increase efficiency, productivity or generally make good continuous improvements. This part of the thesis will give a basic overview of the relevant lean tools for the purposes of the Lean SG.

1. **Just in Time (JIT)**

Just in time in manufacturing is a Japanese management philosophy and a stockless manufacturing approach that aims to produce a specific item at a specific time with specific quality and quantity. This philosophy is based on the principle that the items will be produced just on demand, this mean using JIT requirements (equipment, resources and labor) as minimum as possible (Shivanand, 2006).

The JIT principle is considered as a journey and is not a fixed destination. The goal of eliminating the waste in the manufacturing process and reducing inventory is achieved by coinciding the producing process with market demand so that the “pull system” where the products are manufactured just when demanded are applied. Thus, the company resources will be optimized, and profits will be increased.

2. **Gemba Walk**

Gemba means "where things happen," and Gemba Walk assumes that the management goes around the company exactly where the action takes place (J. Sayer and Williams, 2007, p. 271). Gemba helps that management can more easily see and address problems that may arise at the line level and add more resources to do so. This ensures good flow in the company, while making it easier to drive continuous improvement. In short, Gemba means direct observation. One observes activities at the various stages of the process and focuses on waste and time spent. This is how we can discover areas of improvement. (Bicheno & Holweg, 2016).

3. **Kaizen**

Incremental continuous improvement that increases the efficiency of an activity to produce more value with less waste. Kaizen refers to activities that continuously improve all functions, involve all employees and try always to create a lean culture in the organization.

Maximizing performance by personal and team's level and searching for innovative improvements in every part of the business, should be everyone's job. Employees involvement is essential for organizations improvement and profitability. It can be said that Kaizen is founded on these prerequisites: Collaboration, Teamwork, personal attitude / discipline, improved morale, quality circles and suggestions that lead to improvement and communication. (Bicheno & Holweg, 2016) (Womack et al., 1990).

4. Value Stream Mapping-VSM

VSM is made up of all information and materials required in the organization for a particular product to be delivered and the way the product flow (Chen et al., 2010). By looking from a value stream perspective, it is about looking at the whole picture in the organization, and not just the individual process (Rother & Shook, 2003). VSM is a graphical presentation of each step involved in the process which includes all material, and the flow of information needed to bring the product from order to delivery (Bicheno & Holweg, 2016)

5. Cellular Manufacturing and layout design

To manufacture all or part of a production unit, equipment, people and workstations are combined and organized in a way that support process flow in the cell (Wilson, 2009, p. 214-215). In order to increase the effectiveness of cellular manufacturing practices, the cell should support one-piece of flow. For easy monitoring of incoming raw materials and outgoing finished goods, and for movement and space waste elimination, cells should be organized in an optimum layout. In order to reduce the distance of material movement and reduce the transportation time to the minimal (timespan in shifting the products to next station), companies should identify the optimum layout design and select the optimum sequences by developing models to design either multiple or single row cells. The linear, L, U and S shapes are some typical examples of single row cells layout (see figure (2.4)). (Aase et al., 2004). The application of U-shaped layout reduces the number and the motions of operators as it allow operators to perform combinations of tasks as they can move between the U-line two legs something that is not allowed in a linear layout (Aase et al., 2004)

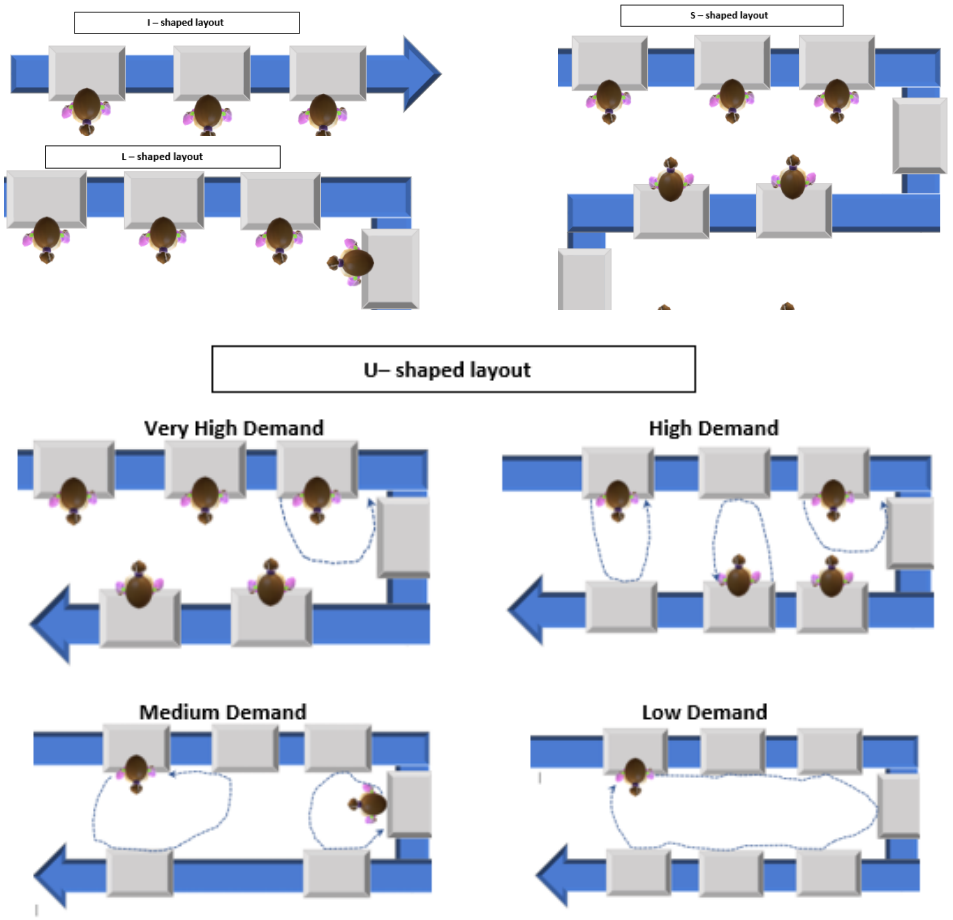


Figure (2.4): Some forms of shaped Layout.

6. 5S model

5s is a tool that helps companies to get an overview of equipment and materials in the workplace, ensuring that the right things are in the right place at the right time. Seiri (Sort) is about sorting useful information and tools in order to make the most needed available, so employees don't have to look for it when it is needed, While Seiton (Systematic) is about putting things in the system by organizing practical sequences into processes so that standards can be established. Seiso (Shine) is about how we experience the workplace, while the task of standardizing on the basis of professionally defined guidelines and procedures is called Seiketsu (Standardize). Shisuke (Sustain) means maintaining implemented improvements and working systematically to improve, maintain standards and change them only when an improvement can be achieved. It is the management's responsibility to train employees 'discipline, so that the 5S system becomes part of the employees' everyday life and work culture in the organization. (Bicheno & Holweg, 2016). It is important to point out that 5S is also an important method for continuous improvement. E.g. if a machine fault is detected when doing maintenance, a root cause analysis should be done and then a correction of the process to ensure that the same error does not occur again is required. This will then be the new standard for continuous improvement. (Bicheno & Holweg, 2016).

2.3 Summary

Following the Design Science Research Cycles of Hevner (2007) used under this thesis, the knowledge base has been built by reviewing and discussing some of the key aspects and theorical undergrounds related to serious game and lean manufacturing in this chapter. This knowledge base is used to create the artifact (the lean serious game) through an implementation of the design cycle introduced in the method chapter.

Engagement, flow, immersion and motivation theories that were introduced in this chapter is applied in the Lean SG design to ensure its effectiveness as an engaging learning tool. In order to avoid the discussed challenges of serious game design, those theories are used to build a list of the game features that the Lean SG strives to achieve while being developed. (the list is presented in the discussion chapter as a part of the design cycle). The elements of game design identified by Fullerton (2014) are used to design the Lean SG. Later in this thesis, the formal elements of Fullerton are employed in order to provide a description of the concept of the game. The Lean SG tries to cover the most part of the presented lean theory in this chapter with a special focus on line balancing, involvement as a tool for continuous improvement and waste elimination. Gemba, Kaizen, 5S, layout design, VSM, JIT are the tools that are applied in the designed game.

3 Methodological Framework

To conduct this study successfully, the methodological approach should be given a lot of time and space. In order to avoid a general methodological rendition, the moments that are specific and essential for this study should be emphasized. The purpose is to identify and evaluate the various methods that are available when implementing data collection, and to justify the choice of method. Methodological knowledge is critical to discuss to what extent the results gives a true picture of reality (Creswell, J, 998). In this chapter, the methodological approach and research strategy and design would be declared.

3.1 Methodological Approach

Looking into methodology theories is a necessary part of any study. This involves reflecting on how empirical investigations should be carried out to test and generate data. The choice of method that is taken should reflect what actually the researcher wants to find out. According to Easterby-Smith. T. J, (2015), the strategy must be related to the problem, and at the same time, the strategy and methods chosen must be in accordance with the worldview of the researcher.

Ontology, Epistemology, and Axiology

Researchers build their studies on the basis of a paradigm or a worldview that governs and guides them throughout the research (Postholm, 2010). Such a study of the research's paradigms helps in defining the basis for the assessment of what is relevant data, theories and perspectives (Tjora, 2012). Therefore, researchers should to be aware of some basic terms as ontology, epistemology and axiology in order to know how they can influence the results of the research. In multi-paradigmatic communities, the consideration of bases of the socially constructed realities is very important. (Berger. L, 1966; Searle, 1995). This section is discussing those bases resulting in that the Lean SG research developed in this thesis is a design science research (DSR is discussed later in this chapter).

Ontologically, the author of this thesis believes in a reality that is Serious games are a useful tool for learning and training. Based on this reality, a solution is developed to solve a problem that the targeted group has. The author believes that many other solutions based on the same reality could be developed and satisfy the same need. This view has an obvious contrast with the positivist ontology, the author is comfortable with multiple, contextually situated alternative world-states. This view differs again from the multiple realities of the interpretive

researcher, in that the multiplicity of world-states is constrained by one fixed underlying reality (Vijay et al.,2019). This view goes align with the ontology of a design science researcher.

Epistemologically, In this study, the author is based on a knowledge ground in order to be able to solve the problem of designing a software simulation that illustrates some of main lean manufacturing concepts in a way that tries to balance pedagogy with gameplay. Through the building and evaluation process of the Lean SG, the author would contribute in solving the question of how to balance pedagogy with gameplay in serious games in general. Epistemologically, this fit with the design science research as a design science researcher is considered as a pragmatist (Peirce, 1931) where Iterative circumscription reveals meaning (Knowing through making). An artifact are developed based on a piece of information that is seen factual by the design science researcher. Throughout the circumscription process, it becomes clearer what that information means. The description of the behaviour of the artifact are the information and to what degree this behaviour acts predictably, the information is true. This dependence of the researcher on a predictably functioning artifact gives DSR's epistemology a feature of a natural-science research and a flavour of instrumentalism (Hendry, 2004).

Axiology is the science of values, it is about the values an individual or group hold (McGregor & Murnane, 2010). This study starts with studying and getting better understanding of the environment of serious games development in UiA to open the doors for creative manipulation. An essential motivator that a researcher has is the self and community valuation of the work and efforts. Axiologically, the Control of the environment and creative manipulation are highly valued by design science researcher. Ambiguity are more acceptable for a design science researcher than for a positivist researcher (Hevner et al., 2004).

3.2 Research Design and Data Collection Method

In fact, various choices must be determined when conducting a study regarding to who and what is to be investigated, and how this is to be carried out (Johannessen et al., 2016). Therefore, choosing a research data collection method as well as research design is an important part of any study. The term method originally means the road to the goal (Kvale & Brinkmann, 2009).

3.2.1 Theoretical Approach

An important objective of studies is to integrate theory and empirical data and to ensure this integration. Several approaches such as the deductive and the inductive approaches can be chosen and used. Both the deductive and the inductive approaches starts with determining the research question, but they differ in the starting point. The inductive approach starts from data moving to theory by summarizing theorical statements, developing theories or general conceptions that tries to answer the problem. On the other hand, the deductive approach starts from an existing theory and moves to data by finding out the particulars of a specific problem. (Johannessen et al., 2011). Postholm (2010) claims that there is a challenge when using the inductive approach since the performance would be affected by the researchers' experiences, personal and theoretical standpoints. the researcher's academic affiliation and subject traditions would surely affect the direction of the researchers' attention and his choice of what is interesting in a research. When it comes to this study, the researcher's knowledge of the topics through studies, together with the study's open and exploratory problem, makes that the choice should fell on a hybrid approach.

In order to take an overview of what has been done before, the study should start with spending a little time to study some existing theories and researches in the area of the research problem. This would be a way to develop theorical sensitivity and to make it easier to give a direction to what can be relevant to look at rather than taking a theorical standpoint. (Strauss & Corbin ,1990). An approach starting from empirical data, but that accept the meanings of theories and perspectives in advance and during the research process and that takes into account that research projects often face unforeseen challenges, could be relevant for this study. The abductive approach has these features and selected for this research (Alvesson & Sköldberg, 2009).

3.2.2 Research Design

Yin (2007) defines the research design as "A logical plan for getting from here to there, where here may be defined as the initial set of questions to be answered, and there is some set of conclusions (answers) about these questions.". A research design describes how the research activities are organized and how data collection is to take place. This should be done in a way that allows one to answer the problem in the best possible way. Design science research is considered suitable for this study. The main reason is that the aim of this study is to increase learning by developing a solution to better engage and motivate students to learn

by actively participating in the learning experience in a virtual world. Serious game and its related theories will be used to develop a solution since it is considered as an effective and engaging method of training and learning that establish a compromise between playfulness and educational aspect (Dunbar, 2014). Markkula (2016) confirms that Design Science research is appropriate to stratify when the aim is to design or construct new/improved products, artifacts, or innovations. Therefore, Design science is the primary research approach of this research.

Design science research is defined by Hevner and Chaterjee (2010) as "a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to body of scientific evidence". Obtaining knowledge of problem-solving process during artifact development is the primary principle of DSR (Hevner & Chaterjee, 2010). Constructs, models, methods, or instantiations are built to address special problems, and considered as the artifact of DSR. Nunamaker and Chen (1990), defines instantiations as "A proof by the construction". Typically, Instantiations take the form of intellectual or software tools and terms the feasibility of the product. (Hevner et al., 2004). The objective of this thesis is to develop an artifact that takes the form of an instantiation "a Serious Game".

Building and evaluation activities are to be conducted in a design science process (March and Smith ,1995). While the building activity is about constructing an artifact that is supposed to solve a problem, the evaluation activity provides objective evidence that the requirements are fulfilled and the artifact has the ability to satisfy the needs founded in the real world. Further, they emphasize that importance of justifying and authorizing the results to clarify how the artifact contributes to problem solving. Hevner et al. (2004) pointed to this issue by encouraging the researcher to consider the loop going back to the knowledge base instead of focusing only on the building and evaluating activities, at the same time, he emphasized the contribution of the knowledge to the knowledge base.

Iterative circumscription is considered as an essential part of the design science research methodology where the reality and knowledge are iteratively revealed from the research effort. In this research, design alternatives are generated and then tested against requirements and constraints. The outcomes of those tests are used in the improvement of the next iteration of the design alternatives following the Generate/Test Cycle presented by Simon (1996). This would ensure the improvement of artifacts where creativity and the technical feasibility is present when addressing the underlying objectives (Werbach & Hunter, 2012).

Design Science Cycles

In literature, it exists some frameworks and guidelines to conduct a DSR such as the DSR cycles (the design cycle, relevance cycle, and rigor cycle) that are inherited from IS research framework as shown in figure 2 (Hevner et al., 2004). This approach locates DSR between a knowledge base and a conceptual environment. The design research draws its relevance from the opportunities and the problems that exist in real world. Later, the results of DSR are applied into the environment to solve problems. At the same time, rigor draws from the knowledge base, the applicable knowledge that allows a researcher to do the build and evaluate activities of the design research. Later, the research contributes knowledge to the knowledge base. As shown in Figure (3.1), the focus of the relevance cycle is on field testing and requirements while the rigor cycle focuses on grounding and additions to the knowledge base. Hevner draws attention on the importance of the obvious determination of these three cycles in DSR. (Hevner, 2007).

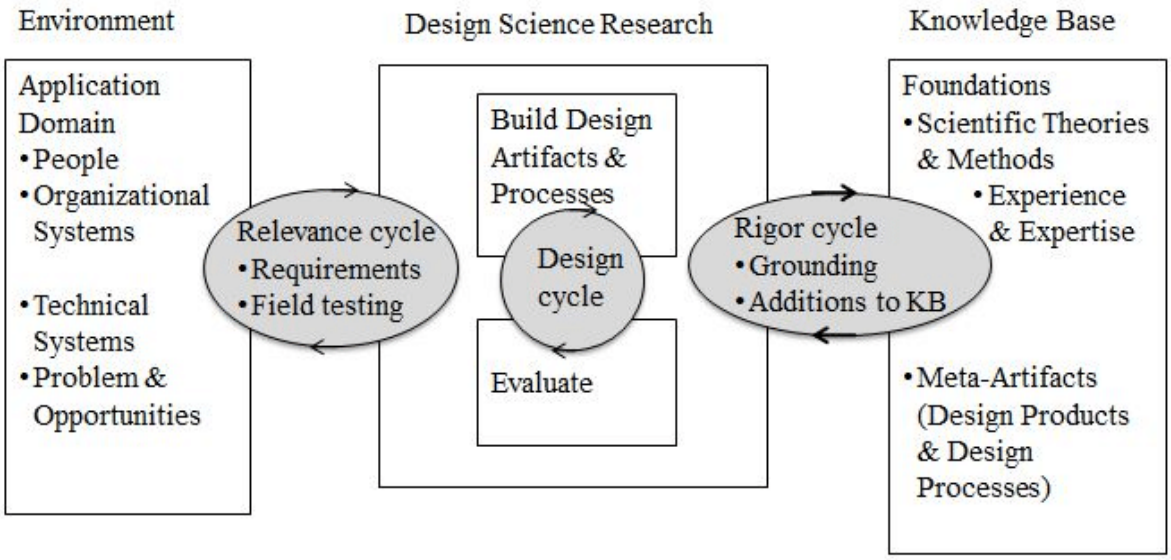


Figure (3.1): Design Science Research Cycles (Hevner, 2007).

In this research, the DSR cycles are clearly determined. Serious game design and lean manufacturing are the problem space (The conceptual environment) of this research. Furthermore, the relevance cycle is determined by defining and analysing the requirements, opportunities and constraints, in the domain of lean understanding and Serious Games. Field testing is done by the evaluation of the game artifact to acquire confidence in its ability to achieve the intended mission of balancing gameplay and pedagogy. On the other hand, the theoretical frameworks for Serious game design, lean manufacturing researches and the DSR method makes the knowledge base of this research. The rigor cycle includes the observation

of some existing Serious Games that is used as a benchmark especially those artifacts existing on Wegas (the web-based serious game authoring and execution platform used in this research). The design cycle ‘s building and evaluation processes play as the core of this research and are described in the following section.

The Design Cycle of Lean SG

00Since it is preferable to follow an order throughout the design process and since the developed artifact is a software product, the Generate/Test cycle (Simon, 1996) and (Marfisi-Schottman et al. ,2009) vision of serious game production were inspiring in planning and developing the design cycle. The reason back combining those two views is that Marfisi-Schottman et al. (2009) don’t cover the iterative aspect of game design (Marne et al., 2012), however, the model provides a guideline for this research by showing which steps are essential to develop the serious game and to give it a structure. In this research as shown in figure (3.2), the author developed five phases to form the design cycle that is executed in many iterations. This step by step approach using iterations would allow quick fixes and prevent rework (Garris, Ahlers & Driskell, 2002). In this model, for the first, the required goals and objectives will be clearly identified. Second, the requirements will be analysed. Then the concept phase is discussed. At the production phase, the game will be produced. And at last, the testing phase is used to grasp which aspects of the system are working and which are not and make changes based on this.

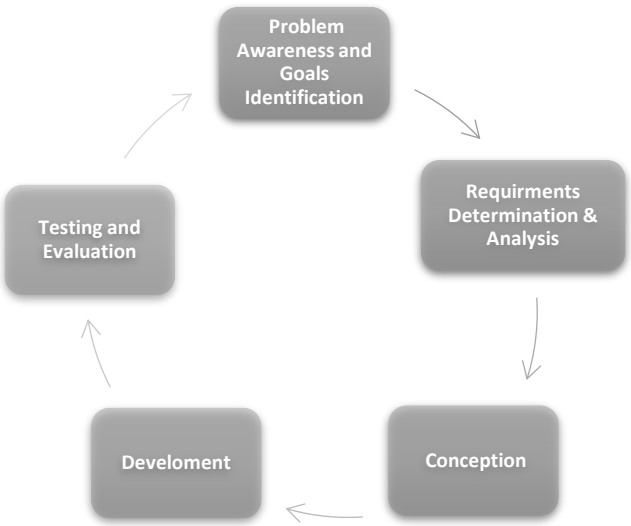


Figure (3.2): The design cycle of the Lean SG.

Phase 1: Problem Awareness and Goals Identification.

A fully understanding of the encountered challenge followed by basic analysis and ingenuity possess designer's ability to work towards a solution efficiently and effectively as it allows a greater focus of designer's full creative potential.

The first step in this phase is to get in touch with the stakeholders, discuss and highlight the problem and identify their objectives, needs and specifications. It is planned to conduct some meetings with the client in order to decide which expectations they have for the artifact and which educational topics to be covered by the lean game. This includes identifying the educational purposes and the pedagogical objectives of the game to ensure that the Lean SG is satisfying those goals under the design and development phases. Later, when adding the gameplay elements, they should be built around the pedagogical content that is analysed and identified in this phase in order to achieve a balance between learning and fun in the game.

Phase 2: Requirements Analysis

Requirements are considered as an essential part of software development projects (Carpers, 1996). In this phase, it will be crafted a set of game rules and materials that makes the base for writing the design document in the next phase. Zowghi and Coulin (2005) highlight the importance of analysing the application domain, identifying the sources of requirements and analysing the stakeholders. This will be done as a part of this phase. Furthermore, the functional and non-functional requirements needed for developing the game are determined. Several researches had the focus of developing lists of requirements needed to develop effective games. The requirements take into account game features and elements are identified in section (2.1) of the literature review. The design principles by Benyon Turner & Turner (2005), will be used to help in designing a smooth and easy user interface.

Phase 3: Conception and Quality Control

New configuration of new and existing elements will be used to envision creative functionalities. What needs to be learned by players and how this can be achieved is explored at the conception phase. Furthermore, this phase includes the determination of the structure, players, features and rules of the game. This is also a phase where a general description of the scenario is created and evaluated. At last the created concept will be presented to the client in order to use their feedback in refining the concept in an early stage.

Phase 4: Production

It is the technical part of the process, where the resulted concept of the game is executed. In order to develop the Lean SG, some development toolkits are selected. The gameplay and the interface design of the created concept can be adjusted under the production phase for better design quality. In iteration 1, as the game has a play-based design process, it is planned to develop a paper version prototype of a digital game where extensive storyboards, design documents and basic graphical elements are to be created by the author of the thesis. Many programs will be used to develop those documents which are gathered and used to develop the prototype of iteration 1 where the aesthetic aspects of the final version of the game will be absent. This version is just to define game's core mechanisms and fundamental rules.

In iteration 2, the refined concept will be executed in the platform used on this research (Wegas). The production phase of iteration 2 will involve many parts from different fields. In order to make the graphical work of the game, a cooperation with the multi-media and design department at UiA has to find place. The designer of the game must contact persons working for the Weggas platform in order to learn how to use their editor for making the lean game. If the editor doesn't support a planned feature or an activity of the lean game, people from Weggas will help in programming and adjusting the editor so that the designer can perform the planned activity. In the next iterations, the user interface including the layouts, pictures and other features are enhanced. The designer has a plan of focusing on developing a simple interface that partly seems as a website so that the user feels familiar with the game. As the same time, graphics and visual effects are to be used to make the game more attractive and real.

Phase 5: Testing and Evaluation

Rogers et al. (2007) states that a designer should consider the effectiveness of evaluation as a research on its own in order to get back a better evaluation data. It is important to conduct a playtest after each iteration of the design and development phases (Robertson & Howells, 2008). Playtest is a well-known method in evaluating game design (Korhonen, 2010). (Fullerton et al., 2004). Once constructed, the serious game will be evaluated to test both its effectiveness as a teaching tool and the degree of entertainment that it provides. At first, the created concept will be self-evaluated by the use of the requirements list developed in the last phase. The list will be used to check if the concept of the game covers the analysed requirements or not. The first version of the game will be tested and evaluated by game's

stakeholders and some of “Serious games in higher education project" team members in Norway and Switzerland. Some students are asked to play the game and tell about their experiences of playing when the game is prototyped on Weggas platform in the next iterations. Any deviation from the expectation is to be noted and explained. The feedback gained in this phase is used to adjust and improve the artifact in each iteration.

For evaluating the usability of Lean SG, observational user methods looks relevant since this research is aimed to look in deep to how users interact with the game to identify the design issues that affect game usability and that have impact on game’s ability to achieve the balance between learning and gameplay, and then to make adjustments based on this data. However, it is required a fully working prototype for conducting an observational analysis that can result in a huge amount of data that needs time, human resources and cost to be processed and analysed something that is restricted in this research due to time limitation. Fullerton (2014) encourages the use of feedback as frequent as possible as it can prevent a lot of work. As a solution to this problem, the design cycle of the lean Game is carried out in several iterations which starts with developing and testing a rough version of the Lean SG and use the earned feedback in enhancing the artifact in the next iteration and so on. This approach is called “vertical slice quality” and was used by White and colleagues (2011) in their studies. As discussed in the research design section, each iteration consists of five phases where the evaluation phase is the last one. This would help in generating quite enough data to be analysed at each iteration. The result of data analysis would be used to improve the game and to enrich designer’s underlying data to be used on other iterations of the game. the Serious Game Usability Evaluator (SeGUE) developed by Moreno-Ger and colleagues (2012) is used for usability testing the Lean SG.

Right after their interacting with the game, end users will be interviewed to get a better understanding of informants' experiences and their reflections on the usability of Lean SG to cover the research question, this is discussed in the next section.

3.2.3 Research Method

The determination of what method to choose, is seen as a pragmatic choice, where the problem as well as the researcher's preference play an essential role Ringdal (2013). Qualitative and quantitative strategies are seen as different methods for research, where a significant distinction is made in how data is collected and analysed (Ringdal, 2013). Most of

the research, both qualitative and quantitative, is done within a defined scientific subject area or within a defined research topic (Tjora, 2012).

In this study, the main research question is aimed to look in deep to how students react with the lean game to get an answer to the question about game's ability to balance between entertainment and pedagogy. As the lean game is based on some theorical assumptions to generate this balance between gameplay and learning, the evaluation phase is essential to confirm and improve those assumptions generating data and contributing to the knowledge base. Based on that and on the fact that this study uses a single case study (the lean game) with few numbers of participant/testers, the choice would fall on using the qualitative method for generating primary data. The qualitative strategy gives the researcher a chance to seek to identify how the phonomimes in a society is created through action, interaction, opinion and attitude (Tjora, 2012). On the other hand, quantitative strategy seeks to generate data that is associated with quantifiable units such as numbers and sizes. While quantitative studies are suitable for a large number of units in a more standardized structure, the qualitative data collection is often better suited to deeper studies of few units and is characterized by Easterby-Smith et al. (2015) of being open and more exploratory. This openness can a researcher experience when using the interview method, that is typical for qualitative researches, and that gives the opportunity to the researcher to ask follow-up questions that otherwise would not be included. Furthermore, the interviewee may come across topics that were not intended in advance, but still turn out to be reasonable to elaborate.

The collection of quantitative data requires more prior knowledge than in qualitative data collection because data is generated for statistical comparison, which means that the collection must be done on exactly the same theorical basis. Therefore, for this qualitative study the Step-deductive inductive method (SDI) that do not require a lot of knowledge in advance, is chosen as a theorical approach. This goes along with the abductive approach that suggests that the researcher should start with a certain understanding of the theory surrounding the topic that would make a base for a process of parallel work. It is natural at this phase that the researcher makes theorical assumptions based on past experience and theory gained through studies. However, the researcher should get as far as possible away from these during the preparation of the interview guide

Thus, the qualitative approach allows the researcher to study a single case study in depth. This gives the researcher an insight into the phenomenon being studied. By using a qualitative approach, I will be able to cover important elements of the study. A qualitative

approach is thus well suited for the study's formulated issues. For interpreting the findings, the logical connection between data, assumptions and criteria would be drawn carefully.

Interview as Data Collection Method

In qualitative researches, interview stands as the most widespread data collection method (Tjora, 2012). According to Kvale and Brinkmann (2009), through interviews, a researcher can understand the world from the interviewee's side. Research interviews are based on daily life conversations and is a professional conversation that exchanges views between two people on a topic that occupies both parties (Kvale and Brinkmann, 2009).

According to Johannessen et al. (2011), the use of a structured questionnaire limits the possibility of getting information beyond what is asked. With the task's abductive approach and problem area, it is in the researchers' interest to keep an open mind about what would come out of the data collection. Because of this, it is natural to exclude structured data collection such as quantitative questionnaire surveys. On the other hand, since the research area deals with people and tries to understand their reflections, the researcher considered it necessary to use an interview as a data collection method to elucidate the complexity and nuances involved. The main target of the interviews in this study is to study opinions, attitudes and experiences to the informants. In-depth interview method is based on a phenomenological perspective and seems to be perfect for this study, since the researcher aims to understand the informants' experiences and their reflections on the usability of Lean SG as an entertaining learning tool.

Population

The population in the social sciences context refers to all units the research question includes, and is often called the universe (Johannessen et al., 2016, p. 242). The purposeful sampling in quantitative studies means that the sample is often found randomly, so that the researcher can do statistical generalizations. Actually, a researcher has a lot of ways for strategic selection, and for this task criteria-based strategic selection could be suitable where some criteria is set for who could perform as informants to the research assignment. For this task, the criteria for the selection could include that testers should be full-time students. It is an absolute criterion that the informant should have an underlying understanding about the lean concept. In order to gain a broader understanding of the topics covered by the research assignment, it is also desirable that the informants have different genders and different relationship to games (people who may not play games regularly and regular gamers).

In some cases, the snowball method could be used for the selection of informants. The snowball method is a method that is suitable in cases where there are few available respondents to approach at the start (Johannessen et al., 2016, p. 119). To ensure that the informants are able to respond to the problem and to reduce the task's classification bias, the case university would be involved in the process of selecting the informants. When the interviews are completed, the informant would be asked if he / she had any suggestions for further interview objects.

Interview Guides

For this study, it is appropriate to prepare two different interview guides, one for students in the case university and one for the trainer. It is suitable to distinguish these two as the teacher side and the student side will have different perspectives. The interview guides will start with some background questions like, “Can you give a brief introduction to your background as a gamer, have you played a serious game before?

The second part of the interview guides will include some question relating to informant’s reflection on the Lean SG as a learning tool. (See appendix A)

3.3 Summary

This chapter has presented an essential part containing information concerning the heart of the research. It is the explanatory part where clear information and details that allow implementing and repeating the research was provided. This included a full description of all instruments to be used. Moreover, it was identified if they were legitimate and relevant for making this research. As the method chapter was written in an early phase, it introduces a method to be used for full implementation of the Lean SG. However, the Lean SG was not fully implemented as a consequence of many challenges. One challenge was the inherent multidisciplinary nature of serious game design, which led to that the author had to make researches in many fields to be able to design the game. This evoked the need of face to face meetings with the concerned group something that was not possible due to The Corona Epidemic. In addition, the epidemic was the reason for losing some time as the author of this research had to stay home and take care of two little children since kindergartens were closed under the research implementation.

4 Discussion

This chapter discusses the design cycle of the Lean SG providing a detailed description of the process of creating and testing the artifact (the Lean SG). Then, the chapter introduces a summary of the design cycle research trying to answer the main research question.

4.1 Research Implementation and Discussion

This part explains how the design cycle of the Lean SG has been carried out. Coming up with ideas and then bringing them to life is the all part of this process. The creation of a good game needs a great input to the mind and senses. The ability of generating workable ideas and solutions to problems is enhanced by understanding of the system to model in the game. (Fullerton, 2014) Therefore, the process was starting with getting a broad understanding of the learning objectives and the desired outcomes of the educational offering of the game. Analysing the domain and stakeholder's needs and identifying the requirements were the next to do. Followed by generating the concept of the game which was executed and developed in a later phase. The testing and evaluation phase came at last where the game was tested by game's stakeholders and was subject to a self-evaluation and a pedagogical quality check to ensure game's learning effectiveness. This chapter has two sections that wrap up the first two iterations of the design cycle. Due to time limitation, iteration 2 was partly implemented.

4.1.1 Iteration 1

Iteration 1 of the design cycle started with determining the intended educational goals followed by requirements analysis and creating a game concept which was self-evaluated, and quality checked by some professional people. This resulted in a paper version prototype which was tested at last.

4.1.1.1 Problem Awareness and Determination of the Goals in Iteration 1

The problem was analysed at the start of this phase. Serious games are making a great progress both in business and in the educational sector, this resulted in a great need for contributions both in terms of research and development. This study is a part of the DIKU-financed project "Serious games in higher education" that runs at the university of Agder. This project is a spin-off from the internal LUF project "Digitization of project management courses". Here, attempts are made to introduce more student-active learning forms using serious games in teaching. This thesis adds a new research effort to this project. The main

goal is innovating and strengthening students' learning and competence in lean manufacturing with the help of "serious games", as a digitized project-based learning method.

In order to identify the goals and the learning objectives of the game, some meetings with the concerned group were conducted. The first meeting was held with the head of the lean course at the university of Agder where the content and the learning outcomes of the course were presented and discussed. The purpose of the meeting was to identify the intended educational concepts to be taught by the students while playing the game. Creating a game that shows the impact of lean implementation in organizations in a short time, was the overall goal. A serious game that gives students the chance to play a scenario as realistic as possible seemed to be good to achieve this goal.

Lean line balancing was selected as the main topic for the Lean SG as continuous flow production and line balancing is one of the most important industrial manufacturing concepts (Leone et al, 2003). In order to create an ideal game environment, it seemed logical to include an assembly line within an organization as the setting of the game. Players would then be asked to make improvements in order to make the line ergonomic and keep it small, logical, open, flexible and sequintial. To be able to win, players should use Lean tools like division of work, takt time, line balance, optimum cell layout and equipment to integrate. It was decided that the game will be adressing other lean topics while concentraring on the main topic of line balancing. Players should be taught the economies in movement, the optimization of parts presentation, waste elimination and supporting the continuous improvement and involvement. Figure (4.1) shows the main intended learning outcomes that the game is addressing.

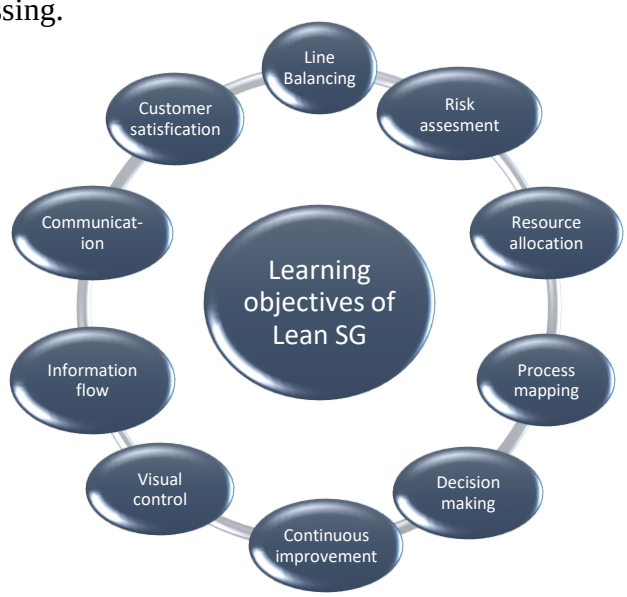


Figure (4.1): The intended learning outcomes of the Lean SG.

4.1.1.2 Requirements Analysis in Iteration 1

In order to capture the requirements necessary to set up the scope of the game, the domain of the game was analysed in an early phase where related documentations were studied to get a better understanding of the scope. This phase is considered as the bridge between the phase of goals determination and game design. Some meetings were conducted with people from the" Serious games in higher education" project to get more detailed information about the needed artifact and their requirements and expectations.

It has been constructed a list of requirements that identifies, categorizes and explain some of serious game elements which seemed valuable for the Lean SG. Literatures on serious games, instructional design, cognitive and educational psychology were reviewed to extract serious game elements which were used to derive those requirements. The list was drawn upon existing lists of game dimensions described in the theory chapter (e.g., Csikszentmihalyi (1990); Bowman (1982); Hamari et al. (2016); Whitton (2009); Fullerton (2014)). Furthermore, and to support those theories, other sources have been used in this section. With respect to Serious game elements, it was among others chosen to seek support in the work of Fullerton (2014), which sheds light on and explains several game's elements in detail.

Those requirements helped in organizing the main findings from serious game literature review, especially those extracted from empirical studies evaluating the effect of instructional games on learning outcomes. It also helped in addressing the key question of the research and was the base of the self-evaluation made in this research. Table (4.1) presents the requirements of the Lean SG, including the description of each requirement.

Table (4.1): Requirements analysis.

Requirement	Description
Clear goals and objectives and	-The game should clearly define its targeted learning outcomes. Those outcomes should be listed, and the designer should explain in which way they are addressed in the game. (Biggs & Tang, 2011). All the elements of the game should support the intended outcomes (Kessels et al., 1996) -The pedagogical purpose that the game is aimed for, fits with the objectives of the game. -The objectives should be challenging but also achievable. (Whitton, 2009), (Fullerton, 2014).
The required player competences are clear.	The designer should identify all the skills needed to achieve the wanted situation. (Kessels et al. ,1996)
Enough time to achieve the learnings objectives	The game gives players the ability to absorb the content offered by the game by providing them sufficient time. (Gardner, 1993)

Clear rules	To keep the game playable and to make players focus on game's learning intentions, the game should have clear rules that regulate gameplay (Fullerton, 2014), (Whitton, 2009), (Salen and Zimmerman, 2003).
Challenge and competition. **Control and Balance between player skills and challenge.**	-The resources are the limiters and should be realistic and fit the learning purpose. (Fullerton, 2014). -To design a challenging game, the game should provide goals with uncertain attainment (Kagan, 1978; Eifferman, 1974). Uncertain outcomes can be applied using several ways like hidden information, randomness and multiple level goals (Malone, 1981). -The game should react in a consistent, challenging and exited way to player's actions. -The game shouldn't penalize players for the same failure more than once. (Fullerton, 2014). -To ensure the balance between frustration and boredom, the designer should use flow (Girard, E M. 2013). -The game should have conflicts/barriers/ challenges that are not too easy but also not too difficult. The player should be pleasantly frustrated without losing the desire to continue the game (Csikszentmihalyi, 2014)
Meaningful Human-Computer interactions	-Players are more motivated when the game has a high interaction quality. (Fullerton, 2014). - The use of intuitive and meaningful Human-Computer interactions expands serious game's acceptance by players (Kirriemuir & Mcfarlane, 2004).
Direct and instant feedback	-Player's stimulated behaviour should be concentrated on the learning activities and a direct feedback should be given to the player on their behaviour. -The provided feedback can hint players towards the right direction. (Fullerton, 2014)
Cognitive immersion/player choice	-The game should give players the ability to make decisions within the characters situation (Jennett, 2008). -At the start of the game, the decisions are limited and then it starts increasing and falls near the end of the game (Fullerton, 2014)
Mixed reality: mixing digital and physical aspects	Mixing digital and physical aspects can help players in physically applying and creating what they have learned. (You & Neumann, 2001) (Ohta & Tamura, 2014).
Social affordances	Every game has a time and space frame that points the fact that a game is being played (Salen and Zimmerman, 2003). The game should have a social setting in which characters are placed. (Fullerton, 2014). -The setting is picked up to support the learning activities. The selection of the right setting creates a more fun and engaging game. (Salen and Zimmerman, 2003).
Immersive story line/ Narrative	-The game is based on a story that draws people into playing and places the learning activities in a fun and engaging way. (Fullerton, 2014). - The story should be co-authored by the interaction of the player and the game (Rooney, 2012). - The tension of the game rises at the start of the game and falls at the end (Fullerton, 2014). -The player should find interest and pleasure in the game without external effects. This could be achievable by letting the learning goals be meticulously knitted to the scenario (Habgood, 2007; Ryan &Deci, 2000)
Communication and instructional support	-The game should use a concise language to communicate with users. In addition, the game should provide instructional support to help players understand how to play (Robertson &Howells, 2008)
Rewards	The game should have at least one reward mechanism (Glover, 2013). Reward gained is increasing as the game is advancing (Fullerton, 2014).
Authentic learning environment	The game should provide an "authentic" learning environment that replicates a real-world experience and gives players the chance to participate in situations that may be inaccessible in the real life (Barab et al., 2005).
The content is pleasurable and has good sources and grounds.	The content of the game should represent the situation of the character's daily lives. And the content of the game is built upon proven sources (Kessels et al. (1996). -The game should have a pleasurable content and push players to think creatively and with fantasy while interacting with it. (Fullerton, 2014)

Choice of attractive educational activities. Decorum relevance and attractiveness.	The correlation between the learning objectives and the missions, characters and settings enhances knowledge transferring to the real life (Ryan &Deci, 2000).-The use of visual and sound effect, an original story line or graphics can attract player's attention and help in immersing players in the game. -The player should have an active role by interacting with attractive activities that fit with the given educational situation (Dascălu et al., 2012).-The game should balance between exploiting the new graphic possibilities and its request for immersion by simulating visual reality as closely as possible (Rooney, 2012)
Compliance to educational context	-It is essential that serious game's sessions are clearly clarified by the trainers in order for players to have better learning experience (Djaouti, 2011). -Hadgood (2007) emphasizes the importance of adding debriefing sessions by trainers where they reflect on game's activities and discuss how the earned skills can be used in real situations.
Curiosity and Discovery	Winn (1981) considered curiosity as the most obvious intrinsic motive for learning. A game can raise the curiosity by adjusting an optimal level of informational complexity (Berlyne, 1965; Piaget, 1952). The game should keep a balance between simplicity and difficulty with respect to player's existing knowledge (Malone, 1981). -This element can include exploration, uncertainty, hidden information, varying activities, Surprise, and randomness (Mautone. Et. el., 2008).

4.1.1.3 Conception and quality control in Iteration 1

The conception design phase follows the goal's determination and requirements analysis phases where the game elements are connected to the pedagogical objectives and game's scenario is generated. The Case based learning model was chosen to present the learning activities in the game. This method is useful for professional education as it connects theory to practise and the declarative to functioning knowledge (Biggs & Tang, 2011). The initial idea of the Lean SG was created in an early stage right after the problem awareness where a game was born and played over and over again in my mind. This was followed by writing an email to the project leader "Bonnier" who thought that the initial idea was interesting and worth pursuing. In the concept phase, brainstorming sessions were made to explore the ability to expand the initial idea and make it more innovative and interesting.

The information about the intended goals and requirements identified in the previous phases were used to create the narrative of the game. It was decided that the player will take a role within an organization as an employee who works to implement Lean in order to solve the challenges the organization faces. Since the serious game is developed to be, among others, used by engineers, it was appealing to create a scenario in the field of electrotechnical companies. This choice assumed that engineers may be more motivated when playing in a familiar environment.

The game introduces a workplace of an assembly line where simple components are assembled to the final product. In this system, although the company is able to meet the

required productivity, it has many limitations such as an unbalanced shop floor which results in a large WIP inventory; the distribution of the working stations creates inefficient transportation distances (transportation of material between workstations); searching for parts takes a long time. This leads to low productivity, ineffective resource allocation, and many wastes. While playing the game, the player is in charge of creating a shop floor with balanced resources, less wastes, lower inventory with the lowest cost possible. Throughout the game, players will try to achieve those demands using their lean basic knowledge that should be developed through the exploratory learning experience that the game provides. Consequently, to ensure the learning effectiveness of the game, the designer was searching into subjects that covers the lean line balancing topic while designing the game where many case studies were explored (e.g. "Lean line balancing for an electronics assembly line" by Lam. et. el, (2016) and "Success Case–Study Lean Production in Electronics Manufacturing Workshop" by Olga. et. el, (2011).

The first thoughts about the game concept was explained in a power point document (see appendix B) and was evaluated by the team of "Serious games in education" project in Switzerland. The team demanded that the game will include more graphic and more locations. Afterward, the concept has been refined to satisfy this demand. The next section is providing a general description of the concept created in iteration 1.

General Description of the concept

The Lean SG is a game where the player will be in charge of the lean related changes in a company that produces game controllers and other products. The game controller product is produced in an assembly line that contains seven workstations. The game doesn't contain levels but consists of five tasks where each task represents a step towards the main goal of reducing costs by creating an effective and balanced assembly line. players will be supported with a guideline that roughly shows the required actions to be implemented to satisfy the main task. Players should pay attention to all the information and documents that are received to succeed in eliminating waste in the assembly line and collecting more points.

The game has different locations (the meeting room, the work floor, and the office) in which the player plays his role in the game as in reality, meet other employees and try to solve the given tasks in an engaging way. Providing players the ability to operate in different locations based on how things is done in the real world, increases the potential for the experiential

learning by creating an authentic environment. The concept of the game created in iteration 1 is explained using the 7-formal elements by Fullerton (2014) as shown in table (4.2).

Table (4.2): The formal elements of the Lean SG.

Element	Description
Players	The Lean SG was designed to be a single-player game where the player will take his/her role as a lean adviser who comes with suggestions for improvements that the company can adopt. The player will be interacting with many employees of the company in order to get the information needed for accomplishing the required tasks. This interaction will find place by conducting meetings, sending and receiving messages and communicating with the CEO. The game will be mixing between the first-person perspective and the third person perspective to fit the different tasks and locations. Both perspectives allow players to immerse in the game world (McMahan, 2003; Adams & Rollings, 2007).
Rules	The game has two types of challenges and rewards: -**Main events:** five large tasks that includes several actions/issues to be solved. These tasks yield points to the player. -**Side events:** small events where the player is given some actions to be implemented to satisfy the upcoming events. Those events don't yield points but yield a type of reward named "Hints" that can be used to get help in form of hints throughout the game. In order to win, the player should wisely use his/her hints, this makes the game more exiting and makes a better balance between player's skills and challenge.
Objectives	Players should strive for collecting points in order to win the game. Points is calculated basing on how good or bad player's performance is in improving and reducing the cost of operations in the assembly line. Players should communicate with the right people who can help in providing needed information and coming with good suggestions that helps players in reaching their goals.
Procedure	In order to achieve the learning objectives of the lean game, all procedures needed to fairly cover the lean line balancing topic were analysed. Game's procedures shape the way to play in order to accomplish essential actions (e.g. finding out the required number of operators). Actions to improve the line layout, eliminate waste and setting the best line scenarios to increase the efficiency require other forms of procedures. Players should execute those actions in a certain way and method of play. The game will provide instructional support to avoid the feeling of frustration among players. In addition to line balancing, there will be many other actions covering other lean aspects like decision making and resource allocation. Since the player have different sub objectives and roles in each task in the lean game, different procedures are created to fit the objective and place/time limiters of each task. Those procedures are discussed in the next section.
Resources:	Players can use different resources in the Lean SG to achieve their goals. The time and budget resources that are used for our case, fit in the context of the game and are a part of the learning activity. The game aims to make players more responsible with the use of money, therefor the budget is limited. In task 2, the number of the people to communicate with is limited in order to obtain the objective of communication with the right people and avoiding the wate of time.
Conflict	The Lean SG encounters obstacles that prevent players from achieving their goals directly. Those conflicts make the game more realistic and interesting. The time and resources limits are used in the lean game as they are typical conflicts in the real-life organizations. Dilemmas are another source of conflicts used in the game by driving players to make decisions that requires deep thinking and that don't have a clear best option.

Outcomes	The end state of the Lean SG is not clear. In each phase, the player is asked to make different actions in order to obtain the main goal. To hold players attention to the end of the game, players are not aware of which challenges are they coming to face as the game advances. Since most tasks are depending on player's creativity, players will try to do their best without being completely certain about the last state of each task. The outcome will be certain when players achieve the learning objective. The game gives feedback and rewards on the way the task was played to reflect on whether the planned knowledge is earned or not.

4.1.1.4 The Development Phase in iteration 1

According to Salen and Zimmerman (2003), the early prototype has not to be pretty, it can be some paper versions of a digital game where extensive storyboards and design documents are created. In this phase of iteration 1, the Lean SG concept is transformed to a paper version prototype that describes the game in detail. The different locations of the lean SG were designed and produced by the author. Moreover, the story line of controller's production lifecycle in the different workstations were generated and described in depth along with pictures of all materials, components, facilities and machines used in each workstation (see appendix C). Furthermore, an illustration of the main page of the game was designed using the Wegas platform and a logo for the game was created.

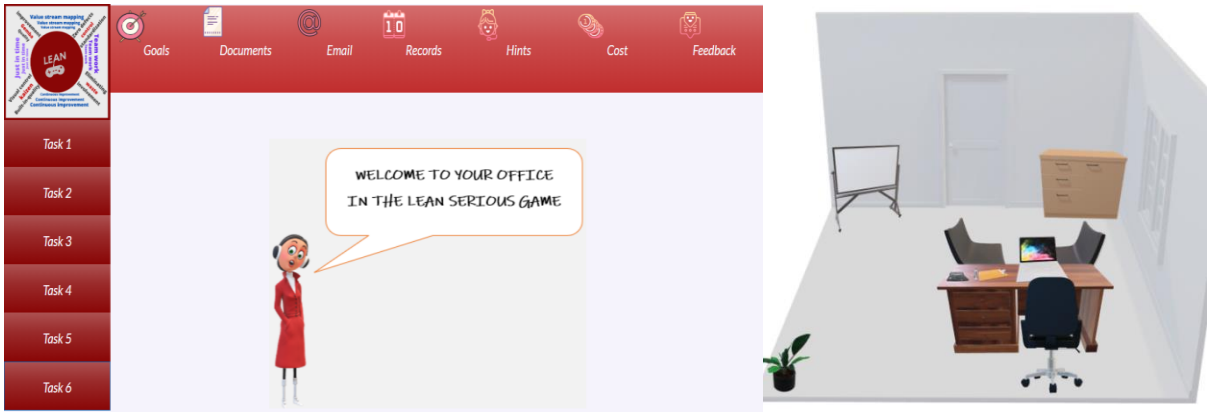


Figure (4.2): The main page and the main office in the Lean SG.

The main page of the Lean SG contains a standard menu that players can interact with while sitting in their offices (figure 4.2). The standard menu includes the following tabs:

1. **Goals:** In the start, this tab will view a page with general goals of the game. After starting to answer the tasks, the tab views the general objectives of the relative task. This tab helps in providing a general idea about what learning objectives and main events that each task address. This supports the exploratory learning experience in the game and satisfies the requirement of having clear goals.

2. **Email**: This tab will include names, positions, and profile pictures of all employees working in the company and the messages sent by them. This meets the requirement of social affordance and satisfies the communication learning objective.
3. **Documents:** This tab contains some relevant documents that students have access to. (it is trainer's task; they can choose which documents to add). Different documents can be given to different players based on the different decisions they make. This creates a compliance with the educational context where trainers can use the game to support students learning process.
4. **Points**: A full answer of a task gives 10 points. Players can get points for successfully performing actions that satisfy the different main events. However, this is not that simple, not enough resources and different barriers and constraints will make the game more challenging and makes the goal of getting a full score of 100, almost not achievable. In some tasks, players could implement some actions that don't satisfy the main goal (not the best to implement) and get no points for them although it can reduce the costs of operations or the cycle time. Players should try their best to get the highest score possible in each task. Having such reward mechanism makes the game more challenging.
5. **Hints:** Players are freely to use hints wherever in the game, where the game will help in solving a problem or viewing a guideline. Some tasks require more hints to show the right direction than others. This makes the game more exciting and challenging.
6. **Time:** Players will get limited time to solve the different tasks. Students should manage the time wisely to answer questions correctly within the time limit. This limitation is considered as a part of the learning activities of the game. The time tab will exist in the main menu but also in the different locations of the game.

A detailed description of the game.

Carson (2000) argues that instead of spelling out a game, players should be invited to explore and discover the story. Therefor it was not desired to provide players a written document that present the story of the lean SG but let them explore it throughout the game. The game starts in the meeting room, where the first meeting between the CEO and the player takes place. The aim of this meeting is to present the situation of the company and explain player's mission by the CEO. The presentation held by the CEO includes many detailed information about the company and is sent to players mail so that they have access to the presented

information when needed. This sharing of company's private information shows the need of transparency and flow of information for better lean implementation in the company.
The presentation includes a picture of the inventory that is divided into two parts (materials and finished goods). It shows that the company held over four months of production in raw materials and finished goods stock. All the games and controllers that the company produces are made to be stored in the warehouse. Then the warehouse receives demands from customers. Two store employees have the job of wandering the warehouse to pick the orders, pack, and ship them. This picture is shown and described to give the player a better understanding of the current situation with its limitations and waste problems (Section 2.2.3) in an attractive way where a concise language is used to communicate with players.

Furthermore, the CEO presents the workplace of controller's assembly line with some pictures informing that the company demands a workplace with balanced resources, less wastes, and lower inventory(Section 2.2.3). The production line has 7 workstations (WSs): Function verification testing (FVT) workstation, Soldering workstation, Assembly 1 workstation, Assembly 2 workstation, Final Inspection workstation and Labelling & Packing workstations. Figure (4.3) shows illustration drawings for the 7 WSs while the operations done in each WS along with their time durations are presented in Appendix (C).

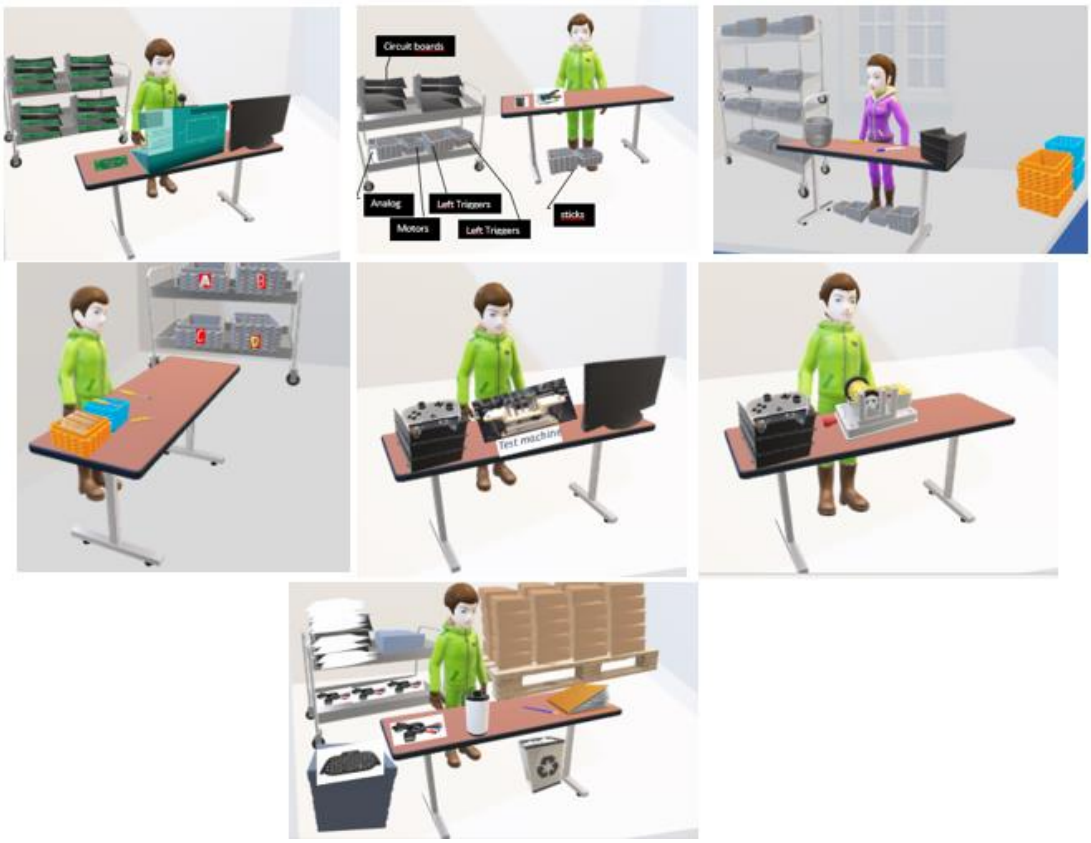


Figure (4.3): The seven workstations.

In the next slide of her presentation, the CEO introduces a map of the organization where the first challenge takes place. Players will be asked to select their new office by selecting among three possible locations. One of the locations is close to the office of the CEO while the second is near to offices of the other employees, and the last is on the point of the shop floor. The hints tab is increased just if the third alternative is selected as this alternative makes it possible for better observation and visual control. Then, a message is sent to the player explaining the Gemba and visual control concepts (Section 2.2.5) as an immediate feedback.

In another slide, the player is asked to deliver an opinion. The CEO tells that the company has determined a fixed budget for developing their website, and the programmer informs that there is still money that can be used to add one of those functionalities to the website:

- A functionality that makes it possible for the customers to complain digitally. (The company has a formal complaint letter template that is used currently).
- A functionality that makes it possible for the company to add weekly votes that customers can replay to (e.g. do you like our new product XXX: Yes, No, don't know).
- Making the website looks more beautiful and attractive.

The hints tab is increased just if player selects the first alternative. As an immediate feedback, a message is sent to the player explaining that customer satisfaction should always be company's priority. In order to consider the complains number as a possible indicator, the company should make it easier for people to complain. (Section 2.2.2)

In order to organize a lean workshop, the CEO informs that a message is sent to the player containing a list over names of some employees, (the message can be seen in appendix D). The player should select the right people to be involved in this process with a limit of 8 persons. The purpose is letting players experience that involving the right people works better in satisfying their goals (Section, 2.1.5.3). While sitting in the meeting room, the player will receive the following popup message:

This popup message has two aims, the first is to change the location to fit with the upcoming activities, while the second is to make the game more challenging. The hints tab is affected depending on which people are invited. The manufacturing planner, technologist, shift leader, logistic, and operators should be invited due to the fact that they are the most essential people

to be involved. The meeting with the CEO is now over, and the player will start to answer the main 5 tasks while sitting in her office.

Presentation of the main tasks of the game

The main page contains a side menu that presents the six primary tasks. A description of the main events of each task is provided where the goals /strategy of the organization in the upcoming period are roughly set out.

Task 1

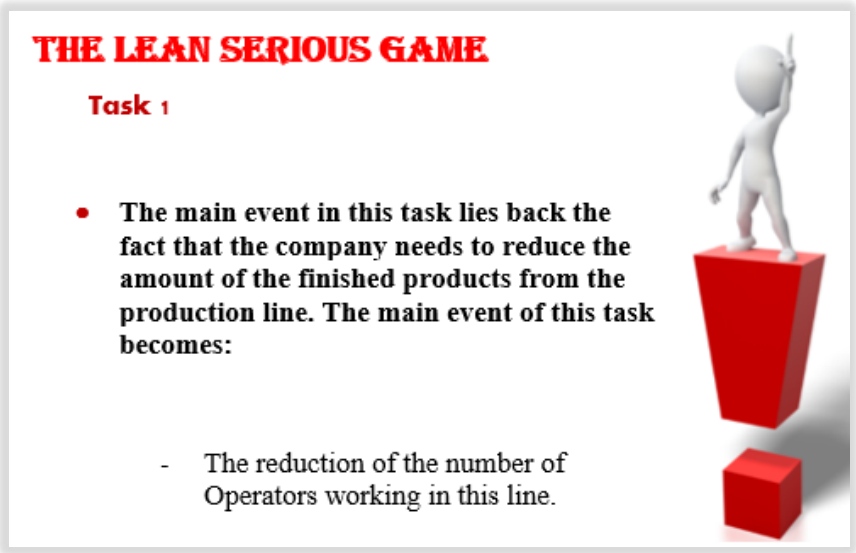
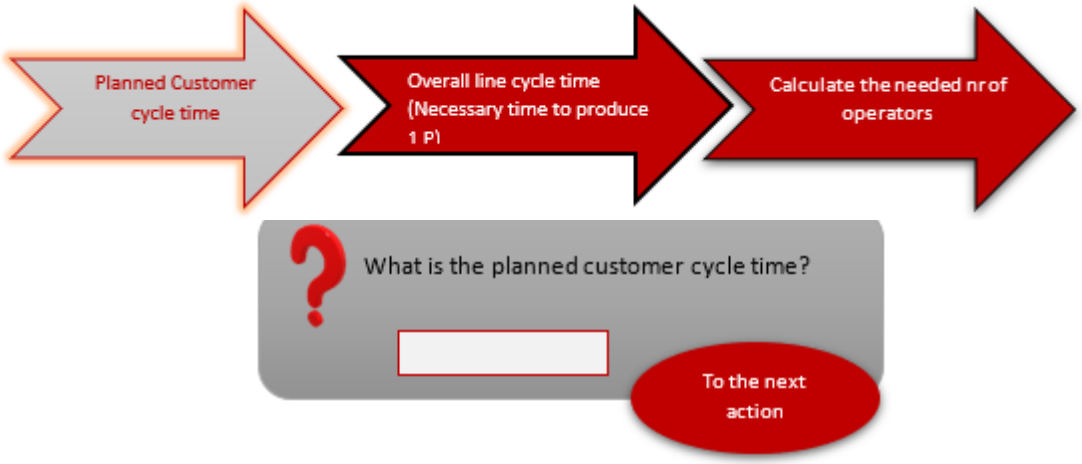


Figure (4.4): The main event of Task1.

After getting the main event of task 1 (Figure 4.4), players have to go through three actions to meet the requirement of task's main event. Pull system implementation is targeted in this task (Section 2.2.1-4). The game provides a guide for the direction that players should follow to solve Task1 by showing the following list of actions to be done,



The first action includes calculating the planned customer cycle time(Section 2.2.4-3), the game provides players help in form of a table that don't just roughly show the general manner

to follow, but also warns players that some specific uncommon criteria should be taken in calculations Like flexibility, OEE. Players should not just use the general formula for calculating the planned cycle time but should also search to learn how to include those terms in calculations to get the right answer. Players will have the ability to visit the documents page where they can explore and find the needed information. The user interface of the game will make it easy to switch between the two pages or view both of them at the same time.

Those calculations are done in the physical aspect, and then entered into the game which satisfy the requirement of mixed reality. The resulted calculation of the planned cycle time will make the base when giving the points while the data entered to the table is partly used to add points. For better compliance to the educational context, the data entered into the table will be sent to the trainer who will use them to know where students strive most and provide more documents and physical teaching on those areas. Furthermore, the game will provide a feedback in form of a detailed proposed solution.

In action2, players have to calculate the overall line cycle time that operators need to produce 1 piece of the product. It is the sum of the cycle time of each operator using the formulas described in (section 2.2.4-3).

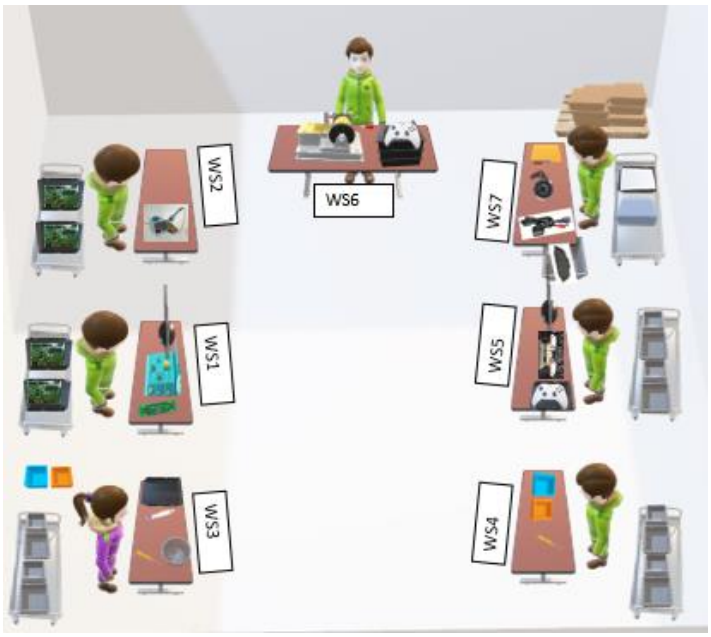


Figure (4.5): The assembly line.

In action2, players are confronted with a new location, the assembly line (Figure 4.5). The purpose is to make the story line more realistic, increase the intrinsic motivation and strengthen the link that learning objectives have to the setting. While standing in their offices, players are able to observe the assembly line by looking through a wide glass window. Player should click into each of the workstations in order to observe from a near distance. The

individual operations in the assembly should be documented to be used to generate assembly plan later (Section 2.2.4-3). Subsequently the necessary process time for each individual task of the assembly should be determined using a real time measurement "stop clock". The determined process time results will be visualized for each of operators using an operator balance chart where the steps carried out, and the respective task duration are compared.

As an example, assume that Workstation 1 is clicked. A new page will be opened (see figure (4.6)) showing a life video of operator 1 while operating. At the same page, a partly filled operator balance chart and a tool for adding operations to it are presented. The description, duration and whether the operation is a value-added, nonvalue-added or necessary operation should be determined and added for each operation. Once the ADD button is clicked, a coloured card with the new added operation is generated. The player should place the card to the right place in the balance chart. For some operations, players need just to determine if the operation is value-adding or not by changing the colour of it. The aim is to provide the needed time to absorb the concept and at the same time to avoid boredom. Appendix C lists the operations of each of the 6 operators along with their duration and colour.

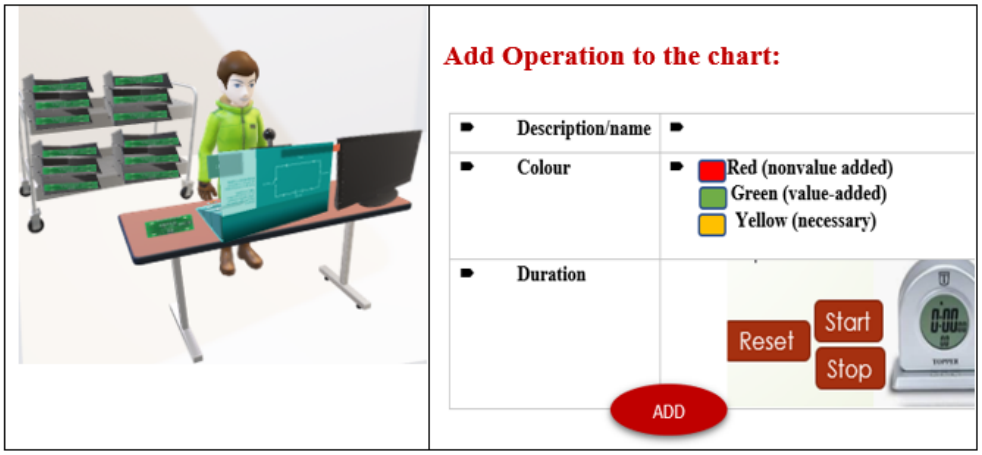


Figure (4.6): Action 2 of task 1.

When the chart is filled out, the overall cycle time can be calculated and entered to the textbox at task1 page. Action 3 includes calculating the needed operator number that is as simple as dividing the result of action 1 by the result of action 2. The activities used in task1 are some replications of real-world practices something that support the authentic learning environment in the game. In order to motivate players, action2 uses intuitive and meaningful Human-Computer interactions and present activities in an attractive way.

Task 2

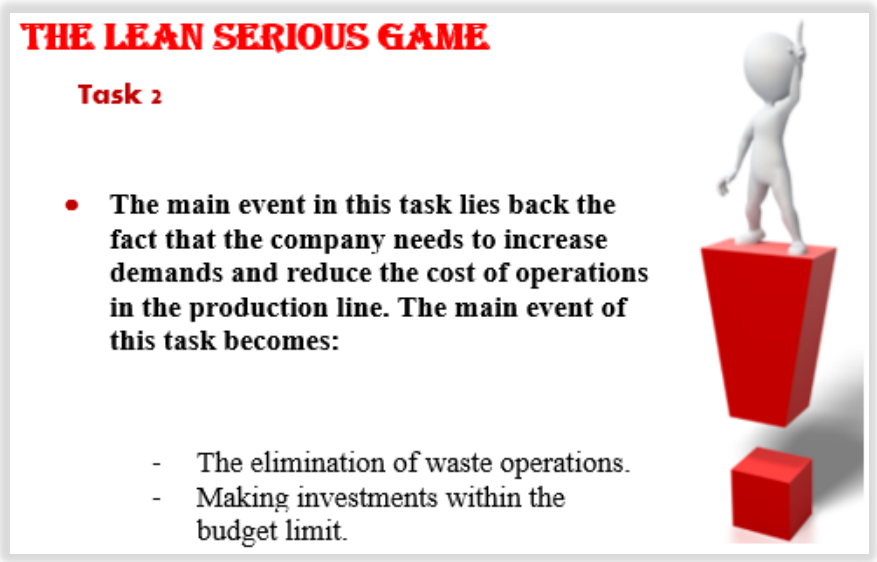


Figure (4.7): The main event of task 2.

As the main event of task 2 shows, this task includes improving the assembly line by making new changes and investments to optimize the line, eliminate waste (Section 2.2.3) and increase profitability. The background for this task is a request received from The CEO about preparing a list of suggestions for improvements that can be applied in the assembly line (Section 2.2.1-5). This list is prepared after a meeting with the lean workshop at the meeting room location. Suggestions and possible investments will stream from the team members and players should wisely evaluate whether to add the proposed suggestion to the list or not. Each of those suggestions has something to do with player's understanding of lean philosophy. There will be more options to invest in than resources can allow, and not all options are wise to accept. Some options do not satisfy the goals of this task, others seem to be beneficial at first but will not help the player to reach the main objective of the game. The content of those suggestions has educational, challenging and pleasurable features as it requires a deep lean understanding and players should use their fantasy to select the right option. One can see that decision making was limited in the first task and then it starts increasing from task 2 which satisfies the requirement of cognitive immersion.

Once the start button for task2 is clicked, the player is placed in a meeting room similar to the one in Figure (4.8). There will be sitting 8 persons (those the player has selected to be involved in the lean workshop). The player should click on a person to let him/her talk and come with a suggestion. The suggestion is to be accepted, rejected, or discussed with other employees in the room before taking the final decision. If players select discussing the suggestion with other employees, they should think wisely and click on the right person to

comment on the proposed suggestion. Players are limited to discuss the suggestion with 4 persons. Players should be aware that some opinions are misleading.

Figure (4.8): The meeting room.

This human-computer interaction and the immersive decision-making process increase the motivation for playing the game and makes player more curious. To make the game more challenging, some limitations are included in this task. The meeting time is fixed, and the player is limited to talk to max 5 persons and discuss the different suggestions within this time limit. All the suggestions, their corresponded learning objectives, their impact on the cycle time, budget, and points are presented in Appendix E.

Task 3

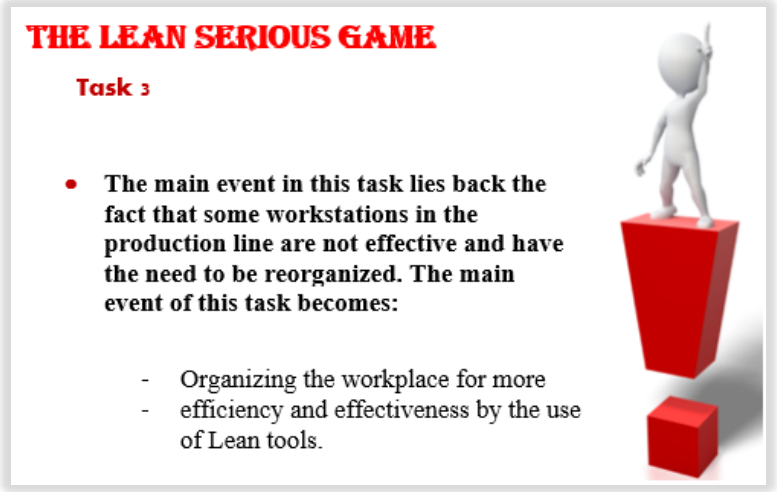


Figure (4.9): The main event of task 3.

The overall learning objective of this task is to know how to apply lean tools and techniques (Section 2.2.4 & 2.2.5) in lines in order to increase the efficiency and effectiveness of their processes. The background of this task is a message sent by the operator working in the assembly 1 workstation at shift 2. Player opens the mail and read the following message

"*Welcome to the company and I hope that everything is going well in your first days in the company. As a well-trained employee with long experience, I can see that the assembly 1 workstation is an unorganized workstation, with more items than required, without organization and unclean. I wonder how you can help in optimizing parts presentation in this workstation with your lean toolbox as an opportunity to eliminate waste. I am attaching (an animation of the movement of the different parts in this workstation?) and a picture of the workstation that you can modify, and I hope you can help by sending back an updated picture to the best state so that we can apply it to real world."* (Section 2.2.5)

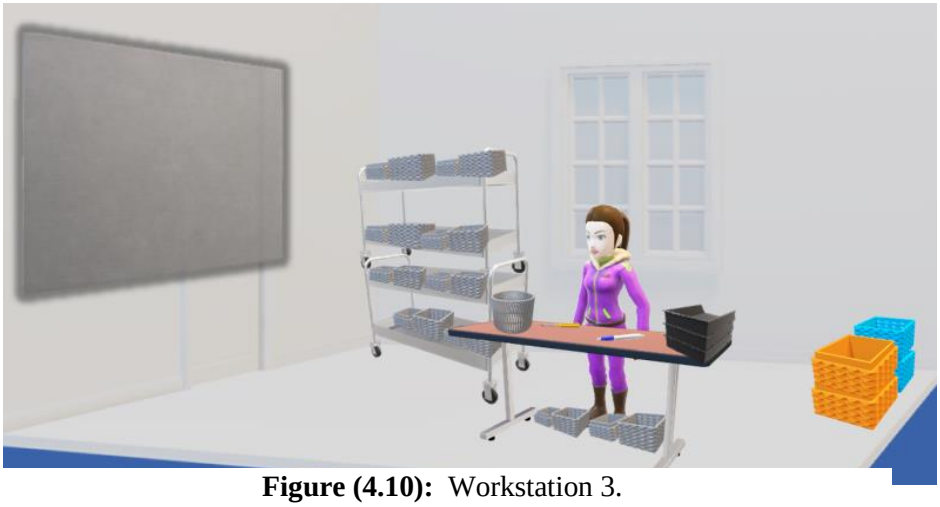


Figure (4.10): Workstation 3.

In this task, the player should use the 5s lean tool (Section 2.2.5-6). The game will give the player the ability to move, delete, change the color, and the position of all the items in the workstation in addition to the ability to add new items and colored tags. The player should start with selecting the items needed and assign an identification tag (red, yellow and green) according to their importance in accomplishing the task (sort); choose the places where to store the items(setting in order); remove unnecessary items (systematic cleaning); find ways of turning these procedures standard (standardization).

To increase the challenge and fun, the player gets limited time to perform the task. There is no definitive answer to this task because it is mainly based on the creativity of players who will try their best and use fantasy to create a good result. The resulted image is then sent to operator 2 who will evaluate it with the CEO and send the feedback later. The resulted image can be sent to the trainer to be evaluated.

Task 4

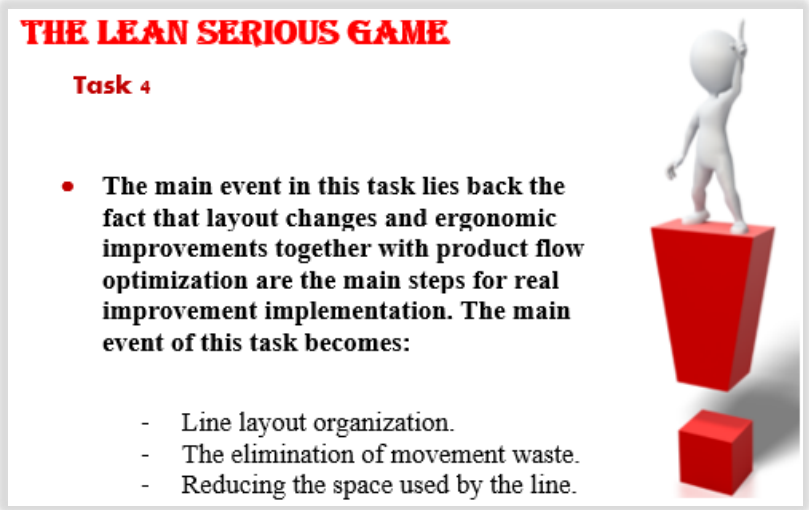


Figure (4.11): The main event of task 4.

In this task, players will try to eliminate the waste (Section 2.2.3) by improving line layout using available tools (Section 2.2.5-5). Players have the potential to change the balancing graph of the assembly line (change the position of the different boxes, rows and so on) (see figure (4.12)). Players should try to eliminate movement waste and create the best possible layout using their lean knowledge and imagination. Throughout the process of changing the layout, the calculated number of needed operators should be taken into account in order to reduce the waste of movement. The new layout should make it as simple as possible for operators to perform their work as each operator will operate in more than one workstation. Players have limited time to finish the job and once the time is out, the new cycle time and the new number of operators needed are calculated and shown on the screen. Based on this and comparing with the best approach, the records are updated.

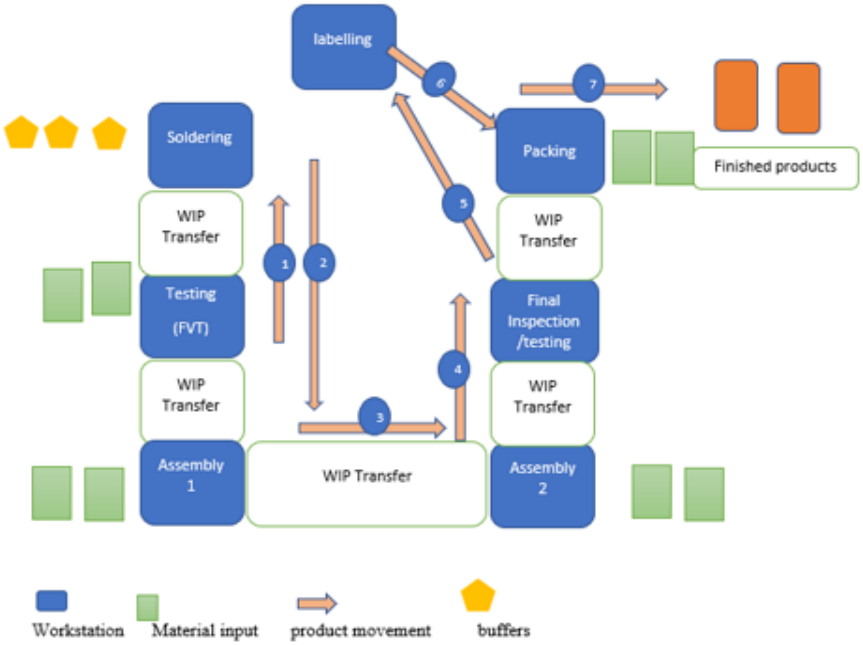


Figure (4.12): Balancing graph of the assembly line.

Task 5

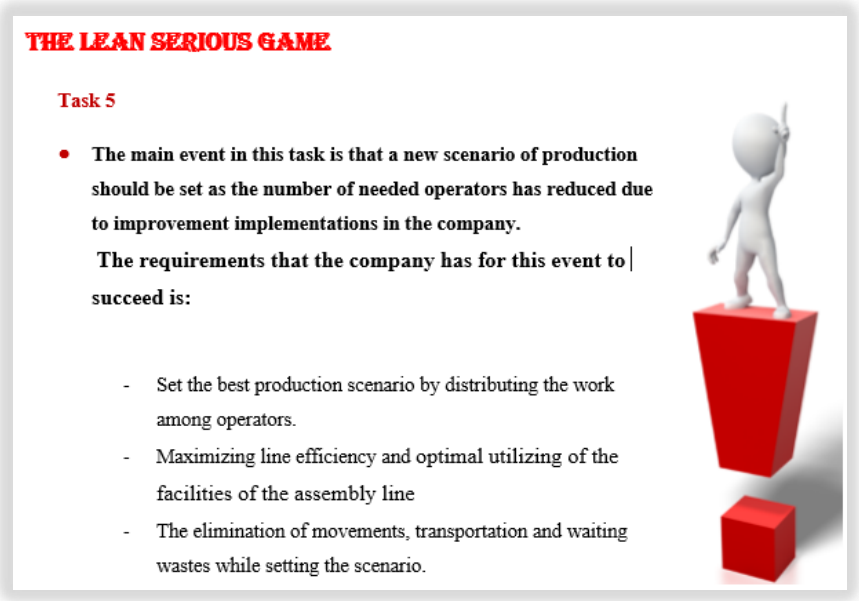


Figure (4.13): The main event of task 5.

In task5, the player is asked to set the best production scenario (Section 2.2.5) to maximize line efficiency by distributing the work among operators to balance the line. The basic idea is regulating each operator's volume of work to the right size in order to avoid any stoppage while sending the work from one station to another. The imbalance between machines and operators should be minimized by reducing the waste operations. This task implies the allocation of operators and machines to operate activities in different workstations in order to optimal utilize the facilities of the assembly line. In this task, the resulted balancing chart (Figure (4.14)) created by the player in task 1 and adjusted throughout the game is presented again for the player who will change the owner of the different operations in order to set the best production scenario. The game provides means to change the chart by deleting, changing the position and the operator of each operation. Players should be aware that the distributed workload for each operator should not exceed the planned cycle time. Furthermore, an optimal utilization of the resources of the assembly line is required, therefore players should use their fantasy and their lean knowledge to succeed.

The resulted chart will show how the situation in the line is changed to be more efficient, effective and flexible. It shows how the cost of operations has decreased as the number of operators is reduced, good investments are done, the layout and ergometric is improved and a better production scenario is set. Here players should understand why they should have accepted/ rejected some suggestions and how their decisions have affected the effectiveness of the production line. It is suggested that students should be asked to write a report describing this chart, how it can be enhanced, what actions they regret making, which lessons they learned from playing the game. To allow students to become immersed, the game should

not be used for other intentions (e.g. grading students) rather than providing a new opportunity for experiential learning in a virtual environment. Having other purposes, can distract player's attention and prevent the flow experience.

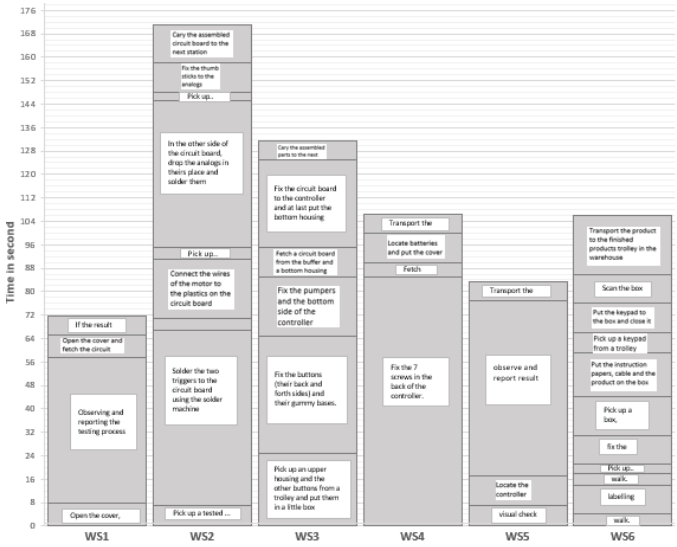


Figure (4.14): The balance chart of the assembly line

When the player is finished with the fifth task, the game is over, and the results are presented on the screen as well as a written evaluation of the results. Furthermore, All the feedback messages that the player has received throughout the game is presented. Some players can feel that they can get better results if they play the game again. The opportunity of playing the game ones again is offered in the Lean SG which is built on a randomized and procedurally generated design. While designing the game, it was focused on giving players a replay value at the same time the designer was aware of not making the game so randomized that player's skill plays no role as a factor in winning. Those, the randomized content has a focus on applying changes that don't affect the world or how the game is played. The randomization that is generated in the Lean SG includes:

1. In task 1,the demand size will be randomly selected by the game, this will affect the five main tasks as the number of needed operators in the line is directly affected (ex, when the calculated operator number is 3, the best production scenario will differ from when the number is 1).
2. In task 2, when the player selects a person to come with a suggestion, the game will randomly select from a set of suggestions. This set differs from person to another. The player should wisely select the right people to communicate with in order to hear the best suggestions that will affect the game in a good manner. A bad choice will result

in a bad suggestion. If players don't realize the trick on those suggestions, they will lose points in addition to losing the time.

3. Rejecting or accepting the suggestions will change the resulting production line in different ways and has big impacts on the following tasks. For. Example some workstations could be dropped out as a result of an information that the game provides through the suggestion.
4. In task 3, the game selects randomly among the three alternatives of workstaion2, workstation3, and the inventory. Once one alternative is selected in the first round, this alternative is dropped from the list of alternatives. This will affect how the assembly line would look like later on the game.

4.1.1.5 Testing phase in iteration 1

This phase of the research cycle has the aim of testing and evaluating the designed Lean SG in order to ensure that the Lean SG keeps the balance between pedagogy and gameplay. This section will start with a Self-evaluation of the Lean SG. Then, the feedbacks received from other evaluators are presented.

Self-evaluation of the Lean SG

Throughout the design process of the lean serious game, the main purpose of creating an effective teaching tool was in mind. The game was designed with the objective of giving players more insight in how lean implementation can create value for organizations. The Lean SG lets players experience that adopting the right techniques to solve organizations problems and the involvement of the right people help in satisfying the goals and strategies of companies. The intended objectives of the Lean SG are presented in table (4.3) and self-evaluated to make sure that the game satisfies them.

Table (4.3): Self-evaluation of the Lean SG.

Requirement	Description
Line balancing and process mapping	A main objective of the lean game is to let players experience how the process of line balancing could be performed and how balancing the assembly line impacts the company in the form of waste elimination, effectiveness, and profitability increase. The game goes deep into the process of balancing the assembly line going from making some necessary calculations like cycle time and takt time, to using some lean tools like 5S. The game was able to define clearly this learning objective in an interested way.
Decision-making	In order to create value for the company and eliminate the waste in the line, players of the Lean SG should make right decisions basing on their lean knowledge. Players is asked to discuss different subjects with other employees to end with making different decisions that influence the final state of the game, and thus the final result.

Continuous improvement:	Continuously throughout the game, the player is seeking to make improvements in order to satisfy the strategy of the company. Involvement stands as a main way for continuous improvement in the Lean SG where employees are involved and heard.
Visual control	The setting and locations of the game is designed to support the visual control concept. E.g. the player is observing the work in the assembly line while sitting in his office through a big glass window in order to get a better understanding of how the waste is happening and how it can be eliminated.
Information flow	The environment of the company is characterized by being transparent where all employees have access to the required information at the right time. The player receives many documents and information from the characters of the game without any reserve in order to make good decisions.
Communication and collaboration:	The player must contact many of game's characters, talk to them, listening to their suggestions, replay to their messages in order to gather points and complete the game.
Allocating of budgets:	The player is restricted with the use of some resources. The budget is determined, and players should use it wisely with the purpose of creating value to the company.
Risk assessment	Throughout the game, the player is asked to pick out actions and evaluate the risk of accepting or rejecting an action. The player should have a good lean understanding for better risk assessment and decision making.
Customer satisfaction	Players should always see from the scope of the customer and seek to meet their expectations while making decisions throughout the game in order to get high scores. The game insists that customers should be heard (e.g. in task 2 and at game's start)

After having evaluated game's ability to meet the intended learning outcomes, the following table is presented to slightly evaluate which of the requirements identified in phase 2 is applied in the game.

Table (4.4): Self- evaluation of the requirements.

Requirement	Description	Not/applied
Clear goals and objectives	The Lean SG was able to address all the learning objectives clearly as discussed above.	Applied
The required player competences are clear.	The Lean SG was mainly built to support the Continuous Improvement and lean course running at UiA, so there will be a compliance to an educational context where the trainer evaluates the right time to start running the game. As the Lean SG provides an exploratory learning experience, it is not necessary that players have detailed knowledge to all the topics addressed in the game. However, a fairly understanding of the main lean concepts (Customer satisfaction, waste elimination, resource allocation, flow, involvement and communication, and Kaizen) are required.	Applied
Enough time to achieve the learnings objectives	Time is considered as a restricted resource in the Lean SG. However, Players of the Lean SG will be offered the required time to understand the idea of each task and to achieve the learning objectives. For this purpose, the time limitation for game's different tasks will be determined in the testing phase based on the time taken to finish the different tasks by the testers. In order to make the game challenging but achievable, the average time from playtest observations is to be used for the most of tasks. As the game	applied

	advances, the time limitation will be increased to over the average to keep the balance between players skills and challenge.	
Clear rules	The Lean SG have clear rules that regulate the gameplay. Those rules have been discussed above. Players will be given a good explanation of those before the game starts.	Applied
Challenge	Throughout the game, players are meeting different challenges that fits with the context of the game. Each phase has its own limiters which makes it challenging. As time, budget limitations fit the learning purposes of the Lean SG, they are used. the difficulty level of the tasks varies from one part of a task to another, at the same time all tasks are achievable to motivate the player to keep playing (e.g. some suggestions needs a deep thinking in order to make the right decision where others requires less skills). To avoid frustration, the game makes that players knows, all the time, which direction to follow. Furthermore, players will try to do their best without being completely certain about the last state of each task.	Applied
Direct and instant feedback	It was designed a tab in the main menu of the game called, feedback where players will get a general description of the right answers after each delivered task. At the same time, some messages will be sent from the characters of the game giving a feedback on the work done by the player in order to highlight the effect of the different actions and decisions made by the player. Furthermore, the rewards system used in the game will also provide a feedback by being increased or decreased.	Applied
Cognitive immersion/player choice	The player is given a role within the organization. The player is a person who will select and come with the best suggestions and solutions for existing problems basing on the undergrounding lean knowledge. At the start of the game, all information needed in order for players to accomplish their role is provided by the CEO. Here, the player is the receiver and the decisions are limited, then the player would increasingly be more active and make decisions (e.g. Making suggestions for different line layouts, and suggestions for investments with the purpose of line optimization).	applied
Mixed reality: mixing digital and physical aspects	While playing Lean SG, players is forced to use the digital and the physical aspects. (e.g. in some tasks, some calculations are done in the physical aspect, and then entered into the game).	
Social affordances	The player and other characters are placed in a social setting that fits the purpose of the game. The game is set in an electronical company. As discussed before, different locations are used to provide a space frame for the game.	applied
Immersive story line	The story is used to emerge players into the game. The game describes a story of a company that recently had difficult time due to market changes and high competition. The player plays the role of the saviour who use his/her power (lean knowledge) to help the company overcome its problems.	applied
Rewards	The game uses different reward mechanics as fairly discussed before.	applied
Intrinsic motivation	As discussed above, the learning goals are knitted to the scenario of the game. this helps in increasing player's intrinsic motivation. The game provides a high-quality human-computer interaction in its different tasks (e.g. in task 3 and 4, the player will enjoy the reorganization process of workstations where all the functions needed to make improvements are accessible). This increases the serious game's acceptance by its players.	applied
Authentic learning environment	The game replicates a real-world experience where all the activities of the game are similar to the ones done in real life.	applied

The content has good sources and grounds.	The content of the Lean SG is basing on a theorical background. Literatures on serious games, instructional design, cognitive and educational psychology and lean manufacturing were reviewed. The theory chapter of this thesis refers to some of the researches that were used in the process of building the content of the Lean SG.	applied
Choice of attractive educational activities and Decorum relevance and attractiveness	While designing the Lean SG and picking out its activities, the designer had that aim of making the game as attractive as possible. Therefore, it was desirable to include graphics, sounds and other effects to engage players more. (e.g. in task 1 players must observe self the different workstations and note the time that operations need to be performed). The Lean SG provides an attractive decorum that fits to the intended learning objectives. To attract attentions, players are set in different locations based on the task to perform. The game makes it possible to interact with other characters of the game. Those characters are also suitable to the scenario of the game.	applied
Curiosity and Discovery	The game includes the elements of exploration, uncertainty, hidden information, varying activities, Surprise, and randomness as discussed before.	applied

Feedback from other evaluators of the Lean SG

At last, the created paper version was tested and evaluated by some of “Serious games in education" team members in Norway and Switzerland. To evaluate and quality control the learning aspect; the concept was presented to the stakeholder and the head of the course for IND418 - Continuous Improvement and Lean (Master's Programme in Industrial Economics and Technology Management, and Innovation and Knowledge Development) at the university of Agder (Knut Erik Bonnier). Besides, the concept has been presented to Grethe Frisli, the project coordinator of the “Serious games in education” project and (Rune Andersen), a professor at UiA, working with the use of ICT in education and in pedagogy as a whole and an expert in serious game design. Furthermore, some meetings were conducted with the programmer “Jarle Hulaas” working with the “Serious games in education" project in combination with the multimedia and design department that will be responsible for producing the graphical elements of the game in the next iterations, represented by Mauricio Cifuentes. The purpose of the meetings with those experts was using their feedbacks to improve and refine the prototype.

Knut Erik Bonnier

Being the head of Continuous Improvement and Lean course running at UiA, made Bonnier the suitable person to test the learning perspective of the game. After testing the prototype, Bonnier concluded that the intended objectives of the Lean SG are satisfied, and he meant that the game covers a good deal of the subjects comprising the lean course in UiA.

Bonnier suggested that trainers should be able to skip some tasks of the game and prioritise others for their students depending on their time, number of students, and the compatibility between the subject covered by each task and the curriculum.

Furthermore, he commented that in task2, students should be able to contact professional people who will provide recommendations required in order for students to take the right decisions.

While testing the game, Bonnier was very excited and reacted: “I wonder how much points I can get if I play this game”. This has aroused the attention towards the task of optimizing the adaptation process to the individual player that is very important to meet the requirement of balancing the transfer of knowledge (the serious part) and the entertainment (the playful part) in the Lean SG.

Grethe Frislie

Being an earlier Industrial management student, having lean as one of her main topics of interests and participating in developing and testing of some serious games while working as a project coordinator for "Serious games in education" project, made Frislie a valuable resource for this thesis. Frislie believed that the game prototype was very interesting and enjoyable as it satisfies the intended learning objectives in an interesting way. She concluded that the designed Lean SG is worth purchasing as it is able to keep the balance between learning and fun.

Frislie highlighted the importance of ease of use, visibility and navigation elements. As described in the paper version prototype, students should use the documents uploaded by the trainer in order to pass task 1 successfully. Frislie insisted that the game should let students navigate easily between the different parts of the system and that all functions in the system should be visible to the user while playing.

Rune Andersen

As Andersen is working with the use of ICT in education and in pedagogy and having a long experience on working with gamification and assessment processes as well as motivation in general, he was considered as a very valuable evaluator. Andersen believed that the game was on its right path towards a good and efficient serious game as it looks more like a serious game than a gamification of an existing subject matter, a very common "trap" in this field. He had not given any comments on how the game could be made better, however he insisted that the essence of game development is test, test, test that will give the best result.

"Serious games in education project" team members

The prototype of the game has been presented and discussed with all project team members. According to Jarle, the game was very interesting with sufficient interactivity and simple user interface. The representative of the multimedia and design department in the project stated that his department is able to produce all graphic elements of the game, but this needs a lot of time and money. The project leader was surprised to hear that the cost of development was too high and commented that the budget of the project is too restricted, and the money can't be spent on developing one serious game as the "Serious games in education project" has many other things to deal with. Therefore, it was concluded that it should be found a way to reduce the amount of the graphical elements in task 1 without losing task's interactivity.

As a result of the testing phase, new requirements and improvements for the next iteration were created:

1. The ability of reusing the created parts, especially those that have high costs.
2. The concept should be refined with economics in mind.
3. The importance of ease of use, visibility and navigation elements in the game.
4. Adding the feature that trainers can choose which parts of the system to be played by their students.
5. Supporting players with the information they need throughout the game by the use of communication in order to replicate a real-world experience and create a more authentic learning environment.
6. The conditions of use should be reviewed with the client more precisely.
7. Applying an adaptation process to the individual player.
8. Seeking ways to make the game more attractive for the players.

4.1.2 Iteration 2

After the testing phase in iteration 1, several attentions were considered to refine the artifact of the Lean SG. In the middle of April 2020, iteration 2 was started to refine game's concept and produce a digitalized version of the Lean SG. It was planned to perform iteration 2 in 5 phases of the design cycle where educators would be involved in the playtest phase. However, there was time to just perform the first 3 phases of the design cycle.

4.1.2.1 Problem Awareness and Determination of the Goals phase in Iteration 2

At the start of this phase, the intended learning objectives of the Lean SG were reviewed. The 10 goals that the game addressed in iteration 1 remain appropriate for iteration 2. Line balancing,

involvement and waste elimination issues were prioritized in the second iteration as in the first. As no complaints were received about the intended learning outcomes in iteration 1 and the head of the lean course seemed satisfied, those goals were not changed in iteration 2.

4.1.2.2 Requirements Analysis in Iteration 2

Basing on the results of the playtest of iteration 1, the requirements described in iteration 1 were reviewed and analysed. All the requirements remained the same, but new requirements were added to meet the needs of the clients. Table (4.5) explains the added requirements in iteration 2.

Table (4.5): The added requirements in iteration 2**.**

Nr	The requirement	Description
1	**Adaptive gameplay**	To some extent, the Lean SG should be customized to each individual player. This makes the game more challenging and appealing (Lopes, 2014). And keep the balance between challenge and skills. (Hoffmann et al., 2019)
2	**Conditions of use**	The game should be compatible with the organizational and technical constrains (Marfisi-Schottman et al., 2014). Those constraints can be the course length and the number of students or trainers.
3	**Reuse of software components**	As the artifact developed in this research is a part of a big project that aims to design several serious games. It should be taken into account that the created parts, especially those that have high costs, can be reused in other games. Taking advantage of the reusable components can greatly help in minimizing the costs of development (Marne et al., 2012).
4	**The estimated cost**	The estimated cost of the artifact, in terms of money and time, should be discussed with the client at the beginning of the project (Marfisi-Schottman et al., 2014). As the estimated cost have not been discussed before the end of the iteration 1, the concept of the Lean SG should be refined with economics in mind.
5	**Ease of use and suitable user interface**	The list of the user interface principles developed by Benyon, Turner & Turner (2005) was used to refine the user interface of the lean game. The list consists of Visibility, consistency, familiarity, affordance, navigation, control, feedback, recovery, constraints, flexibility, conviviality, and style requirements that have been explained in (section 2.1.3)

4.1.2.3 Conception and quality control in Iteration 2

This phase had the purpose of making changes to improve the game design of the Lean SG based on the refined requirements. In order to meet the first requirement of creating adaptive gameplay, some adjustments were made. To keep player in flow corridor, game's difficulty can be adjusted to the player's performance based on the current scoring, while to increase the performance of player, the content and context adaptation to player's performance by current scoring and selection of content can be applied to serious games (Hoffman et al., 2019). In an attempt to customize the Lean SG to some extent, the difficulty of the Lean SG is altered by adjusting the amount of context information given to the player based on their

performance. “Hints” parameter used in this game is adjusted so that it can show different tips for each player based on the current scoring. In addition, the “Documents” that players will have access to under each task, will differ based on players current performance.

The adjustments of the game design that were done in this phase are presented here by reviewing the 5 tasks and describing the changes made to satisfy the requirements identified in the second phase of iteration 2.

Adjustments in Task 1

As discussed in iteration 1, the first task consists of three main actions. It appeared that the estimated cost for developing action 2 is too high because of the cost needed to produce the required videos/animations of the 7 workstations. Besides, the fact that those graphical components are not applicable to be used again in other contexts, made that this activity had to be refined with economics in mind. The adjustment made in action 2 (figure 4.15) includes that the operator working in each workstation will introduce his job by presenting the operations implemented in the workstation instead of showing a video of the process. This will greatly minimize the cost of this activity.

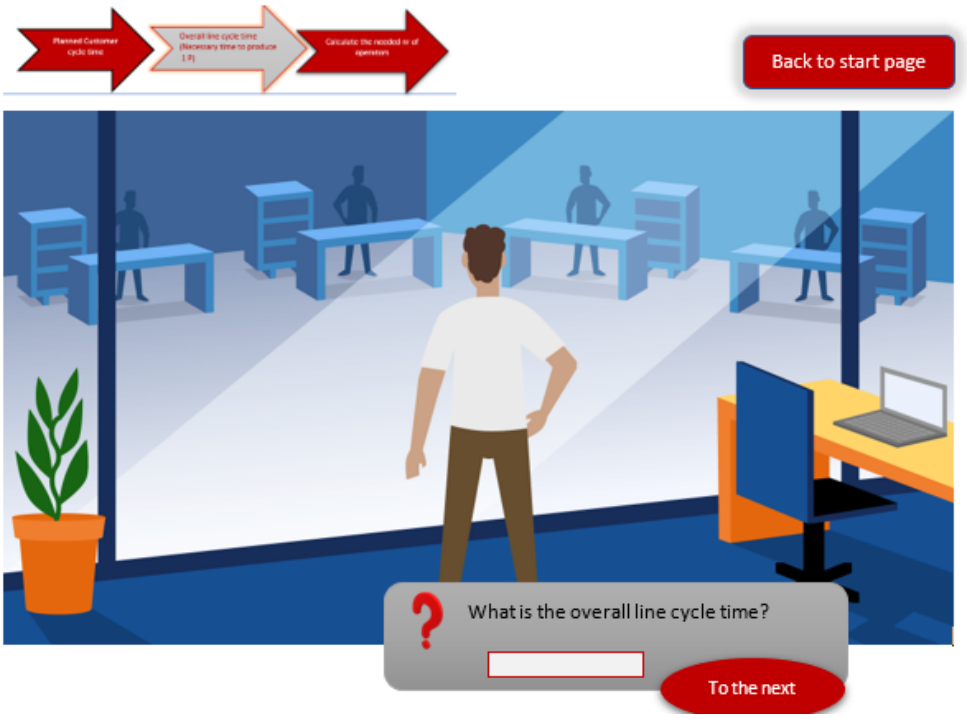


Figure (4.15): Action2 of task1.

As an example, when the player clicks on Workstation 1, a new page is opened (see figure 4.16) showing operator 1 while explaining what happens in this station. At the same time, the operator balance chart and a tool for adding operations to the chart is presented.

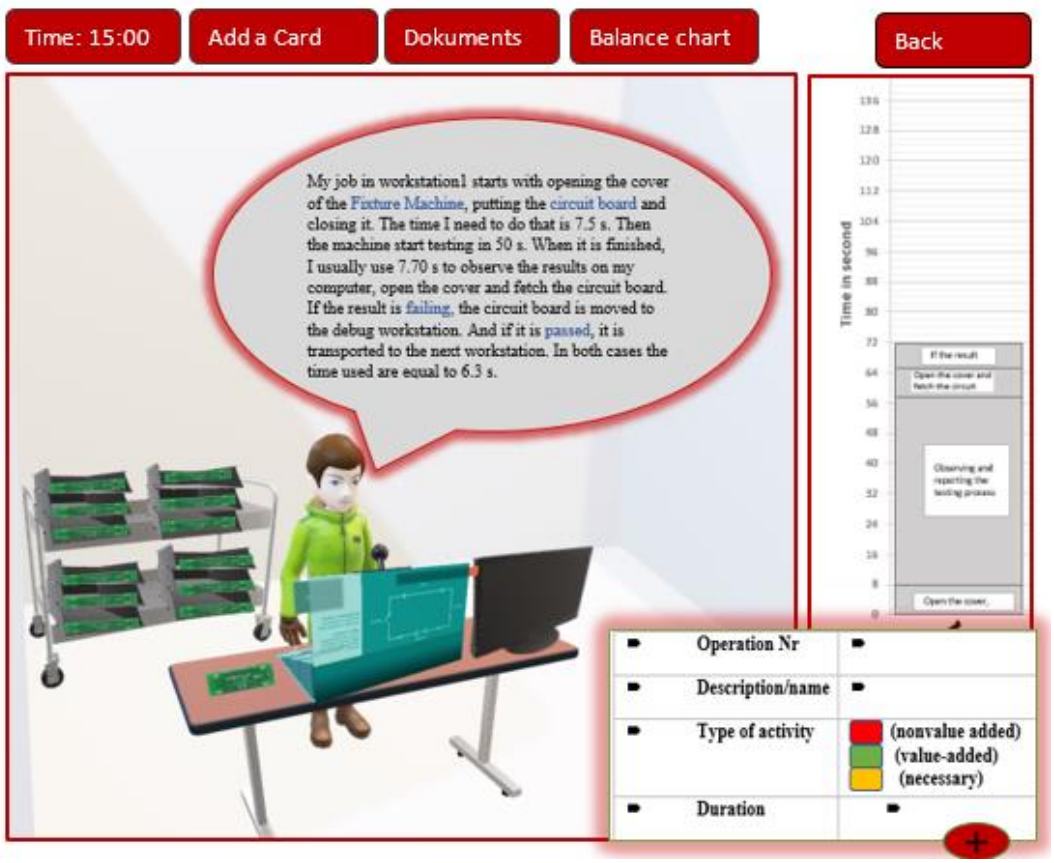


Figure (4.16): Workstation 1.

For ease of use and simple navigation between the different parts of the system, players can easily access all the parts that can be needed while solving this task as shown in figure (4.16). To avoid misunderstanding and to make it easy for players to understand what is meant by the professional or technical words used by the operator, those words is marked with blue colour (e.g. fixture machine, circuit board, failing and passed shown in figure 4.16). Once touched, the game shows an explanation of those words as it is shown in figure (4.17). This helps in getting a better understanding of what is going on in each workstation (what a video does in the last version of the concept).

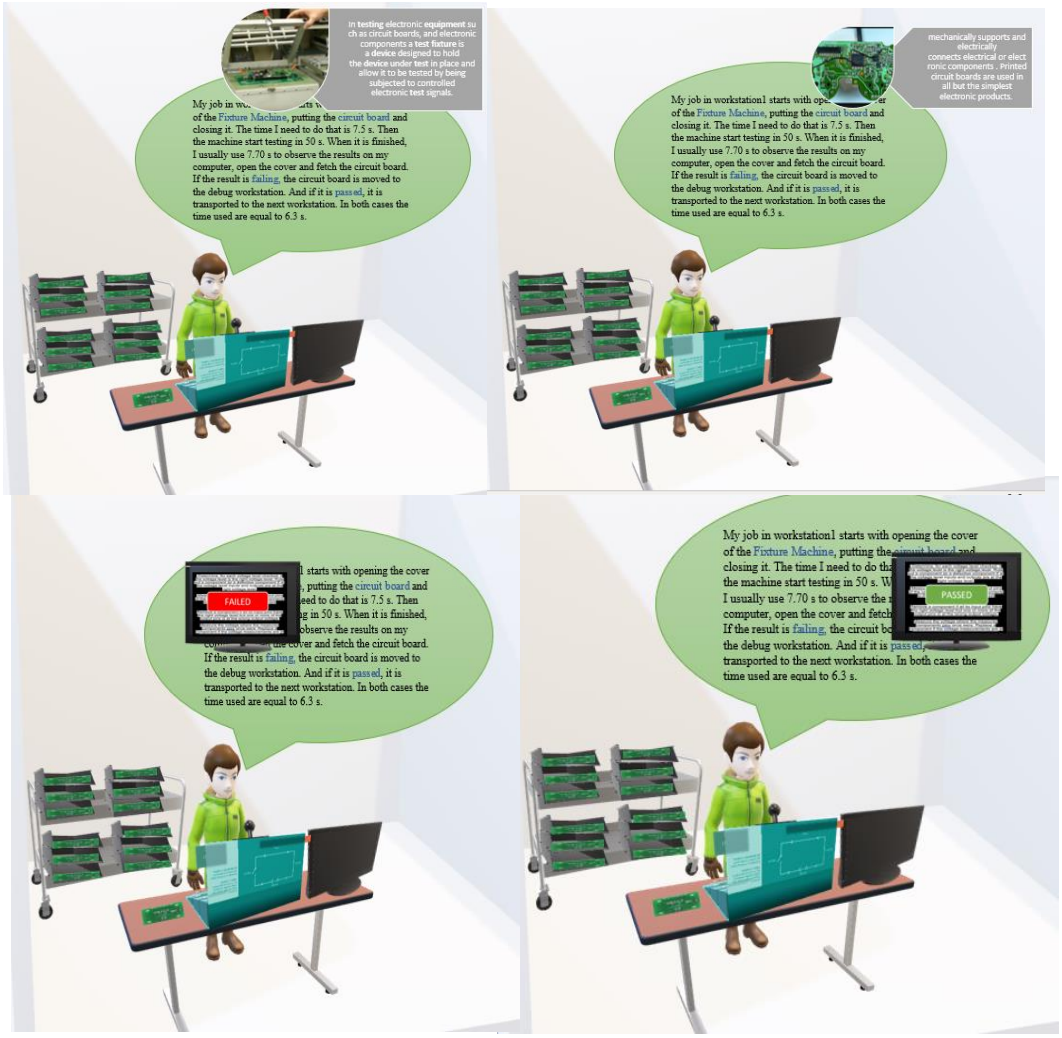


Figure (4.17): Description of workstation 1**.**

Adjustments in Task 2

In this task, the player is meeting the lean workshop that will be discussing the possibility of improving the assembly line by making new changes and investments to optimize the line. In order to recur a real-life experience, the designer has tried to make the activities in this task more attractive and authentic. This section introduces the adjustments made in task2.

After clicking on a person to come with a suggestion for improvement, the discussion of the proposed improvement segment starts automatically. Before the discussion starts, the suggestion will stand in 40 s to give the player the opportunity for self-evaluation. Due to the time restriction of this task, players should use their time wisely and evaluate if they really need to continue discussing the current suggestion before start discussing a new one. Players can listen to as much as wanted suggestions within the time limit. They can accept, reject or discus later a suggestion. The opportunity of postponing the discussion of a suggestion is

limited to one suggestion. The reason for this rule lies back a lack of information needed to evaluate a suggestion and that it is critical to get feedback from professional people to be able to make an evaluation. The player will receive exactly one such suggestion and should consequently evaluate when to use the opportunity of delaying the discussion. When the time of the meeting is over, the game will show the proposed list as in the following figure (4.18):

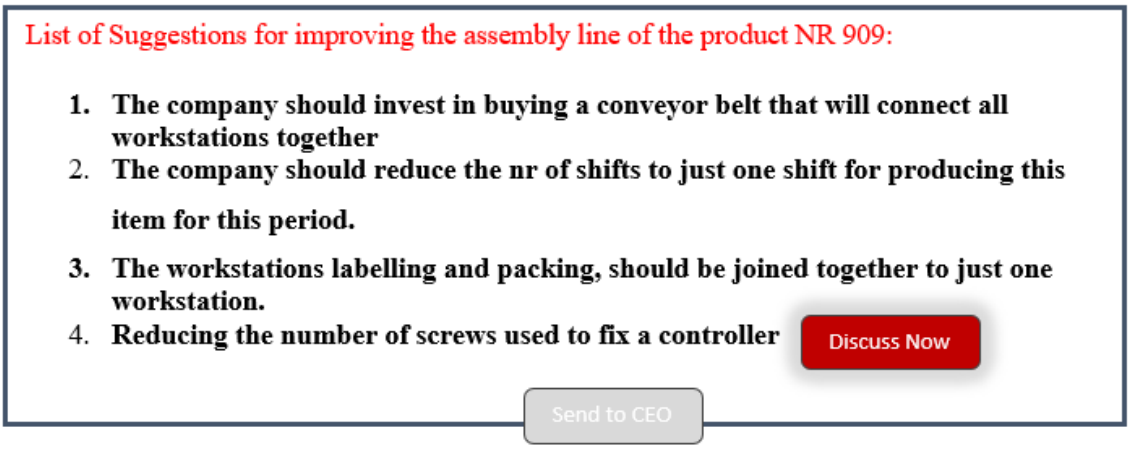


Figure (4.18): List of suggestions.

Th Send button in figure (4.18) is not clickable before discussing the delayed suggestion by clicking on the Discuss button which would orient players to the cafeteria of the company. In the cafeteria, players should talk to the right person who has the sufficient information.

As an example, suppose that the delayed suggestion was:" Reducing the number of screws used to fix the product". According to the following figure (4.19), three persons are sitting at the cafeteria currently: the HR-manager, a programmer and an engineer. The player can talk to just one person. It is important that the engineer will be the selected person in order to get the desired information.

Figure (4.19): The cafeteria

The three employees will comment as the following if clicked:

The HR-manger: "*I agree, this will reduce the cost and the time*",

The programmer: "*I disagree, this can affect the quality of the product*".

The engineer: "*it is possible to reduce the number to 5 screws without reducing the quality of the product, but the process of improving the product will cost". " I need two days to find the right information about the estimated cost"*

After this discussion, players will be forwarded to the main page where they need to evaluate sending the list or sending an alternative message to the CEO as shown in figure (4.20). This evaluation will affect the satisfaction of the management as well as the points. (Appendix F) contains a table that is listing all suggestions that need special feedback to be correctly evaluated, along with the needed information that the right person will come with when selected. The game will randomly select one of those suggestion for each player to keep the randomizing feature of the game.

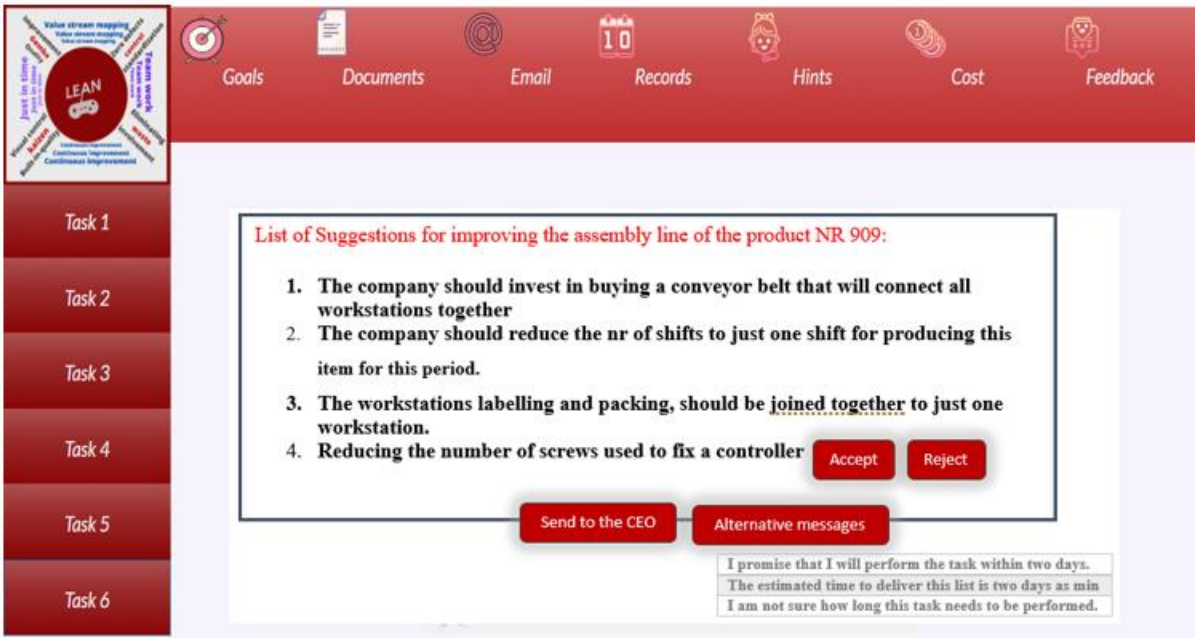


Figure (4.20): List of suggestions in the main page of the game.

This adjustment of adding the feature that gives players the opportunity of talking to professional people to make right evaluations is considered as a response to the feedback given by Bonnier. With the presented solution, the estimated cost was taken into consideration as the game has taken advantage of the cafeteria graphical elements that were produced before. Those elements were used to make the game more exiting and engaging.

Adjustments in Task 3:

According to the previous version of the game, the trainer had the responsibility of evaluating the edited picture of WS3 in task 3. According to Bonnier, this can make that trainers drop this task due to time limitation or large number of students. Therefor it is decided that the game will be programmed to evaluate the edited picture instead of trainers.

Furthermore, as shown in figure (4.21), this task was improved to let players navigate easily between the different parts of the system and that all functions needed to accomplish the task are familiar and visible to the user while playing.

Figure (4.21): Workstation 3 with navigation buttons.

Adjustments in Task 4

In task 4, players were offered the ability to change the balancing graph of the assembly line (change the position of the different boxes, rows and so on), but it will be more attractive to ask players to edit the layout of the resulted assembly line instead of the balancing graph. In this way, players can get better feedback about the impact of their decisions on the assembly line by observing the changes applied there. (e.g. if it was decided to invest in buying a conveyor belt, it will be shown in the assembly line).

Players will be able to rotate and move the tables, operators, trolleys and other things that lies on the floor without being able to change the size, content or the place of the items on tables or trolleys (See figure 4.22). To perform rotation on an item, players must click on the item they want to rotate to select it. Then the rotation icon which can be used to rotate the selected item will appear. The game uses the same technique as in the word program for ease of use and for making the system familiar. Players can also use the toolbar as shown in figure (4.22).

Figure (4.22): The layout of the assembly line.

Summary of iteration 2

During iteration 2, some adjustments have been made to the concept of the Lean SG depending on the requirements analysed for this game. As have been discussed, the results of the testing phase in iteration 1 have been used to update the list of those requirements. The first three phases of the design cycle of this iteration has been fully implemented, however the development and the testing phases were not carried out during this thesis due to time limitation, the wide scope of the research and other complications that have appeared under the research lifetime. The Corona Epidemic was a special challenge that prevented face to face meetings with the concerned group. Besides, it was the reason for losing some time as

the author of this research had to stay home and take care of two little children since kindergartens were closed for period.

4.2 Synthesis

This section summaries the research by providing an answer to the main question of this thesis: ***"How to design a serious game that illustrates some of the main lean production concepts in a way that tries to balance pedagogy with gameplay?".***

A serious game can be designed to enhance players understanding of lean manufacturing by the use of the DSR cycles by Hevner (2007): a relevance cycle, a design cycle, and a rigor cycle. In the present research, it was shown how those three cycles can be combined with other development concepts in order to design a serious game. The Generate/Test cycle (Simon, 1996) and (Marfisi-Schottman et al., 2009) vision of serious game production were used in setting up the steps of the design cycle in order to flexibly implement the DSR cycles. The design cycle planned in this research includes goals identification, requirements analysis, conception and quality check, production and testing phase. This cycle confirms the importance of the iterative circumscription as an essential part of a design science research. Since knowledge is iteratively revealed from the research effort in a design science research, a serious game is designed by following the design cycle planned in this research in order to contribute to the knowledge base.

one advantage of adopting a DSR approach is that, it is not required that a high quality artifact is produced at the start of the design cycle. A roughly version of the game can be produced at the start and evaluated constantly during the cycles. To evaluate and quality analyse the game in the relevance cycle, a field testing in the environment domain has to be performed. The results from the field testing will determine the need for additional iterations. Especially in this research, the DSR cycles of the lean serious game should be conducted in three iterations at least to achieve a sufficient quality design. The process of designing a serious game requires a great deal of time and efforts. Developing an artifact of a lean related serious game requires certain technical skills including design graphic, and a broad knowledge in lean manufacturing, serious games design, instructional design, cognitive and educational psychology.

It is widely acknowledged that an effective serious game should be able to sustain the balance between providing an engaging, motivating and fun experience and constituting a meaningful, valuable learning experience for players (de Freitas, 2007). Consequently,

underpinning serious games with theorical bases from the field of pedagogy and game design is fundamental (Kiili, 2005; Seeney &Routledge,2009). Particularly in this research, the lean serious game is underpinned with pedagogical theories and resting on constructivist principles that espouse the importance of creating an authentic learning environment. The learning process in the lean serious game is situated within the experimental learning pedagogical theory (Kolb, 1984). Lean serious game is a role-playing game that allows players assume roles in a virtual world. Many researchers argued that such authentic environments help in developing new skills such as decision making, social and problem-solving skills (Van Eck, 2007; Oblinger, 2004; de Freitas & Griffiths, 2007; Klopfer et al., 2009). In order to harness and support player engagement that is essential to serious games effectiveness, the integration of gameplay elements is required. Theories of engagement, motivation, flow and immersion are the theorical underpinnings of gameplay of this research.

Due to time limitation, one and half iterations have been implemented during this thesis. The design cycle in this DSR has the aim of designing a Lean Game as a Serious Game that conveys a learning goal of strengthening students' learning and competence in lean manufacturing. In the first iteration, the game was planned to be a single player game without levels but with five main events/tasks which contains 10 intended learning objectives. This iteration resulted in the paper version prototype which conveys the 10 intended objectives and satisfies the analysed requirements that underpin the Lean SG. In the later part, the Lean SG was evaluated through a quality check by “serious game in education project” team members. This check brought some insight feedback and even suggestions from professional people working in different fields: pedagogical, lean experts and people working with graphics and programming. Their feedback was used to refine the concept of the game in the next iteration.

It was extracted from the testing phase and from previous studies that holding the balance between skills and challenge is a vital factor of designing a more effective serious game that balance pedagogy with gameplay. Sustaining learners’ motivation and interest in a game requires maintaining an appropriate level of challenge which should adapt to the player’s skill level (Csikszentmihalyi, 1990).

As serious games are often considered as individual artifacts developed for a limited target audience or company, they have high expenditure and deficient reusability (Doujak, 2015). Due to the fact that serious games gain more acceptance and influence in the e-learning marked and the interest in cost-efficient and customized products are increasing, the need of

producing cost-efficient serious games that can fit big audience and include reusable components are an important factor that should be taken in to account when designing serious games (Dobrovsky et al., 2019). The testing phase has emphasized this factor's role in increasing the effectiveness of the Lean SG. In addition, the conditions of use should be reviewed with the client in a great detail at an early phase of the design cycle to avoid misunderstandings which leads to rework and time and money waste.

In order to get a good learning experience and be immersed, player's main focus should be concentrated on tasks and not understanding how things do work (Rooney, 2016). For this purpose, the testing phase stressed the importance of ease of use, visibility and navigation elements in the game. Furthermore, it has highlighted the importance of supporting players with the information they need throughout the game by the use of communication in order to replicate a real-world experience and create a more authentic learning environment.

The DSR artifact of this research becomes the constructed Serious Game, even though the design cycle was fully executed in just one iteration, instead of a whole design. Through the relevance cycle of the DSR, the Lean SG is applied to the conceptual environment in the context of introducing more student-active learning forms using serious games in teaching. We can assume that the Lean SG can be applied as a serious game to strengthen students' learning and competence in lean manufacturing. Through the rigor cycle, the Lean SG can be mainstreamed to the knowledge bases of DSR and the use of serious games to enhance Lean teaching.

5 Conclusion

This thesis is a design science research (DSR) which destinates for designing a serious game for educators in order to reinforce their understanding of lean manufacturing. The Lean SG employs educator's knowledge to satisfy game challenges and increase this knowledge by providing an exploratory experience. Through this study, the designer of the Lean SG made an attempt in creating a good convergence of the content, the academic theory, and the game design perspectives. The purpose of this convergence is to capture the hypothetical potential of serious games to promote advanced forms of learning. The research has outlined key literatures and theories which underpins and provides a theorical basis for serious game design process.

The three design cycles of Hevner, the relevancy cycle, the design cycle, and the rigor cycle were adopted by the DSR. The used design cycle consisted of goals identification, requirements analysis, conception and quality check, production and testing phases. As designers can never completely predict the play of the game in advance, the used iterative design process is vital in order to make adjustments that have the purpose of driving the game toward meaningful play. Being evaluated by the "Serious games in education" team members which includes experts from different disciplines, is of a big benefit for the Lean SG due to the inherent multidisciplinary nature of serious game design. The evaluation phase has resulted in highlighting the role of certain factors in increasing SG effectiveness such as ease of use, adaptability and balancing challenge with skills.

My contribution through this research is a lean serious game which is based on recognized pedagogical and SG development principles. The game contributes in filling out the knowledge gap in the field of lean related serious games as there are few serious games related to lean production system and line balancing. The Lean SG has some significant differences from previous Lean related serious games. It is a game without LEGO bricks which is common in many other lean games. While focusing on line balancing, the lean SG addresses many other lean related topics, something that seems absent from the most part of lean games that applies specific topics such as "VSM Training kit Manufacturing" and the "5s Training lean" serious games. Furthermore, the lean game is designed to enable continuous development and easy integration of new content.

Finally, this design research enriches the previous studies and works in bringing positive results in serious game exploration to act as an effective learning tool and to support students

by providing a motivating, engaging and fun learning experience. Generally, this study of the Lean SG brings insights and guidelines for future research in the context of serious games, game design, design science research (DSR), or even lean manufacturing in education.

5.1 Limitations

Despite to the positive results of this research, it has some limitations that could be enhanced in future work and development.

1. The author didn't have any before-experience in the field of DSR and Serious games before conducting this research which could mean that this research lacked high serious game skills and resources.
2. As a result of the multi-disciplinary nature of serious games and other challenges as the corona epidemic, the research needed longer time than expected and the Lean SG was not fully developed. The researcher was only able to develop a paper version prototype by implementing one and half iterations of the design cycle.
3. Although the testing phase has involved an evaluation from experts in both the field of education and technology, the playtest has lacked an evaluation from the targeted group which is essential to ensure game's effectiveness as a learning tool.
4. According to Van Aken, a limitation of using DSR in a social context, is that DSR is a still-developing research strategy in this domain. In the Lean SG case, the design has some important social components. This generated the hurdle of searching for efficient methods to handle the consequences of the human agency for creating the pragmatic validity of the artifact as well as getting insight in the mechanisms driving the behaviour of the system.

5.2 Future Work

The constructed lean SG can be considered as a useful artifact that can be applied to the domain of lean education and serious game design even though it has not been fully implemented. Obviously, the Lean SG requires more work to improve its quality and to be developed on the Wegas platform. Future work is needed specially to measure game's effectiveness as a learning tool that balance pedagogy with gameplay by conducting playtests using the method described in this thesis. Some subjects can be added to the educational content of the Lean SG to enrich it e.g. using the game to point out that small incremental improvements in themselves are often not enough to achieve sufficient market share, but that

organizations also depends on major innovations. So-called "breakthrough sequences". Supply chain management is another subject that can be addressed in the lean SG. Besides being a single player game, the Lean SG can be further developed to become a multiplayer game. Moreover, developing tutorials for trainers and students in order to explain how they can use the lean SG in teaching/learning and integrating SG with other digital teaching are other interesting future works. This study provides a direction for future research to investigate the adoption of DSR cycles for designing serious games. In the frame of education and technology, this research could promote more research to investigate the use of serious games for supporting Lean education.

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Appendices

Appendix A

The interview guide:

1. Do you like the game?
2. Was it easy to use the game or the game was complicated?
3. Have you enjoyed playing the game or it was boring?
4. Can you give 3 positive aspects about the game?
5. Can you give 3 negative aspects about the game?
6. What can be improved to make the game more fun?
7. Is there something missing from the game?
8. Is there anything that you didn't like about the interface?
9. Do you think that the level of conflict in the game was suitable?
10. Was the game able to give you insight in how to use leans tool in line balancing?
11. Had the game clear objectives?
12. Was the game able to make you more conscious about decisions making and continuous improvement?
13. Was the game able to view the value of 5s tool in minimizing waste?
14. Was the game able to give you insight in the seven wastes of lean?
15. Was the game able to give you the insight, that working together, involvement and transparency creates more value for the organization as a whole?
16. Was the game able to teach you how to eliminate waste operations by improving line layout, ergonomics?
17. Was the game able to show the value of implementing lean techniques to maximize line efficiency?
18. Is that right that, thanks to the game you realized that the pull production system is better than the mass production system?

Appendix B

Lean Serious Game

The standard menu Bar

- **Goals:** in the start, this tab will view a site with general goals of the task. After each question, it would view the general objective of the relative question.
- **Contacts**: this tab will include names, positions, profile pictures, and contact information of all employees working in the company.
- **Documents:** this tab will view a site where some relevant tutorials and documents that students can read could exist. (it is trainer's task. He can choose whither he want to add something here or not).
- **Records**: a full answer of a question will give the student 10 points.
- **Support:** for each 10 points in records, one point is added to support. The student is freely to use them wherever in the game, where the game will help in solving a problem or viewing a guideline. Some tasks require more support points to provide help than others.
- **Time:** students will get a limited time to solve the different questions. Students should manage the time wisely and collaborate to answer questions correctly within time limit.

The Lean Serious Game

- The serious game aims to enhance students understanding of a number of lean basic techniques. Decision making, Process mapping, Line balancing, Continuous improvement, Visual control, Information flow, Risk assessment, Supply chain management and team work are some potential subjects that the game can address.
- Each of those topics will be covered in a special task, each task includes some questions that cover the topic Satisfactorily.
- The game gives students the possibility to implement methods that create an optimized work systems through both theory and practical experiments.
- As Continuous flow production and line balancing is one of the most important industrial manufacturing concepts, the game is starting with covering this topic in the first task.

The second menu

- **Questions:** when clicking this tab the under figure is shown, the gray row highlight the questions with the done state while the second colour highlights the one with the ongoing state. The last two rows with the pink colour highlights questions with the state of "TO DO".
- **Questions with to do and done states are unclickable. For each question, it exist a deliver and next question buttons at the bottom of the site that will help student to deliver their answers and go to the next question. According to these buttons the under rows will be justified.**

- **Feedback:** here, students get some comments/feedback about their answers to the different questions. It will be some standard comments that will be sent after each question based on the different answers. In addition, the trainer has the chance to write comments.

The story of the first task (Line Balancing)

- The company is facing a dramatic customer call-offs decrease, this have caused overproduction and resulted in excess inventory. The company expect that the demand will increase if the price of the product is reduced.
- The student is presented an assembly system where simple components are manufactured and then assembled to the final product.
- In this system, although the company is able to meet the required productivity, it has many limitations such as an unbalanced shop floor which results in a large WIP inventory, (the assembly of the products in batches generates unnecessarily stock between the work stations), the distribution of the working station create inefficient transportation distances (transportation of material between workstations), Searching for parts, Handling and packaging. This leads to low productivity, ineffective resource allocation, and many wastes.
- The company therefore demands a shop floor with balanced resources, less wastes, faster response time to customers and lower inventory. The company gives this mission to the student.

Question 1

- The text of the first question is:

" You are going to organize a lean workshop, the meeting will cover the topics of line optimization and reengineering, waste elimination and the improvement of line flexibility.

Send invitations to employees(max 7) you think it is essential to have on board"

- To answer the question, students have to
  1. write a message
  2. determine time, place, and persons to invite, taking into account some lean considerations like Gemba, involvement, Transparency and distributed decision.
- manufacturing planner, technologist, shift leader, logistic, and operators should be invited. And the meeting should be at the work place.
- Some dropdown list will be used here.

- At the start page of the first task, an animated video of the production line is introduced.
- The production line has 6 workstations:

1. **Inline loading program; ILP workstation**
2. **Function verification testing; FVT workstation**
3. **Assembly 1 workstation**
4. **Assembly 2 workstation**
5. **Final Inspection workstation**
6. **Labelling & Packing**

- The video will show the operators of the line while doing their normal tasks in the different workstations.

Question 2

- This question is developed to give students an overview of what a line balancing process includes and what they should be prepared for in order to win the game.
- The text of the second question is:

"After the first meeting, you have got some ideas about where to start and what is advised to be done to reach the goal of Optimizing the production line. you need to organize your thoughts in order to identify a « to do list»."

- To answer the question, students need to order the following activities by putting them on proper boxes.
  - 1) Calculate customer Takt Time.
  - 2) Set the target planed Cycle time.
  - 3) Review the content of work on every station.
  - 4) Calculate needed number of operators.
  - 5) Review overall line Cycle time balancing according planned line Cycle time
  - 6) Identify waste operations.
  - 7) Eliminate waste operations.
  - 8) Set best production scenarios.

Question 3

- In order to pass this question, students have to calculate operators cycle time. The under menu with three buttons is shown.

Operator 1 | Operator 2 | Operator 3

- When clicking each of those buttons several things will happen(will be described in the next slides), but the common thing is that a video of an operator operating at his workstations will appear. Students will use a stop Clock(as shown in the figure) as a tool to determine the cycle time of each operation done by the different operators.

Reset | Start | Stop

Question 3

- When students are done with calculating the cycle time for the different operators using different lean tools. Table(2) is automatically generated and shown in the main page of question 3. In addition a full version(that includes all operators) of the combination sheet of the production line and Yamazumi Chart are introduced.
- A support button will be placed at the different pages of task 3. once clicked, it shows how many support points it requires to provide the three types of help. Help1 requires 1 support point, and will be in the form of a randomly filling of some regions in the table, the sheet, or the chart. Help 2 requires 1,5 points and provides further more filling. Help 3, requires 3 support points, and provides a full answers in 10 sec.
- Students will not have the chance to know what the different types of help include before trying them. The goal is team work and involvement(essential in lean)

	Time	Operator nr	Man time	Machine time	Walking time
K/F Station	71.7	1	15.4	50	6.3
FVT Station	49.9	1	13.6	30	6.3
Assembly 1	83.3	2	67	0	16.3
Assembly 2	76.3	2	65	0	11.3
Testing	54.3	3	18	30	6.3
Packing	57.6	3	30	0	27.6
Total			209		74.1
Necessary operator time to produce Controller					283.1

Operator 1

- when clicking "operator 1" button, a video of operator 1 operating at the first and second workstations is shown. In addition, it is presented a table that helps in calculating cycle time for each activity in the first station, the table is partly filled out as shown in the figure.
- Students have to complete the table and fill a similar table for station nr2(FVT) to be able to calculate operator 1 cycle time.

Task No	Operation Description	Operator	Machine	Operator Value-added Activity	Operator Waste Activity	Cycle Time (1piece /batch/t_0)
1	put the circuit board in the fixture machine and close the cover	x		x		7.70
2	Load data and report results		x			50
3	Observing and reporting the inputting data process	x			x	50
4	Open the cover and if the result is failing, the circuit board is moved to the debug workstation. And if it is passed, it is transported to the next workstation.	x		x		7.70
5	Walking to the next suitable station and put it to the FNI buffer	x			x	6.30
						71.7

Question 4

- The text of question 4 is:
- **"Given that the customer demand of around 3520 controllers a month should be fulfilled; there is around 26 working days a month; and the company works 2 shifts a day.**

A. "Calculate customer Takt Time, and select the right answer from the dropdown following list:"

302 | 217 | 185

B. "Calculate Planned line cycle time taken into consideration an (Overall Equipment Efficiency) of 85% and select the right answer from the following dropdown list:"

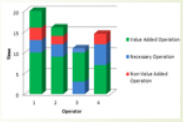
184 | 282 | 111

C. "Calculate the number of needed operators in the line, and select the right answer from the dropdown following list:"

1.5 | o.95 | 2.2

Operator 2

- when clicking "operator 2" button, , a video for operator 2 operating at the third and forth workstations is shown and used by students to calculate the cycle time of the activities done by operator 2. A toolbar of some adjustable boxes with different colours will be available for students to be able to produce a Yamazumi Chart for operator 2.
- The aim of this part of the task is that student get in touch with Yamazumi chart that " is a stacked bar chart that shows the source of the cycle time in a given Process. The chart is used to graphically represent processes for optimization purposes"as shown in figure()

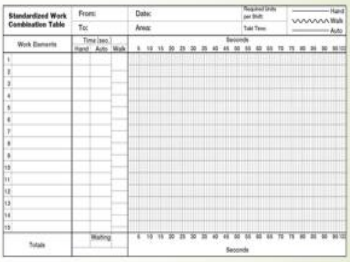


- When clicking the support button that is placed at the bottom of the page, three alternatives of help is shown:
- Help 1: it helps with part A of the question and requires 1 support point.
- Help 2: it helps with part A and B of the question and requires 2 support point.
- Help 3: it helps with the three parts of the question and when selected, table() is viewed to help students in finding the right answer using the proper formals.

A. Available Time	
Production days	
*shifts	
Hours/shift 60*60	
- Maintenance	
Total	
Required line monthly Capacity	
Demands	
Flexibility	
Total Required capacity	
Customer Takt	
Available Time (sec in month) / Required capacity	
B. Planned Cycle Time	
OVE (Overall Equipment Efficiency)	
Planned Cycle Time= Takt Time * OVE	
C. Number of Operators needed	
Necessary time to produce a piece	
Planned Cycle time	
No of operators = Necessary time to produce/ Planned Cycle time	

Operator 3

- when clicking "operator 3" button, , a video for operator 3 operating at the last two workstations is shown and used by students to calculate the cycle time of the activities done by operator 3
- Students are presented a Combination sheet of production line(similar to the one shown in figure but more fancy and colorful) that they should fill out just for operator 3 cycle time.
- The aim of this part of the task is that students get in touch with lean tool called «Combination sheet of production line"
- A toolbar of some rows and lines are presented for students so that they have the ability to remark the different activities (manual, machine, walking, or waiting activities)in the sheet.



Question 5

- The text of question 5 is:

"Where are waste Operations, mark the different waste operations in the balancing graph with the proper waste type?"

1. Waiting waste
2. Movement waste
3. Space waste
4. WIP waste

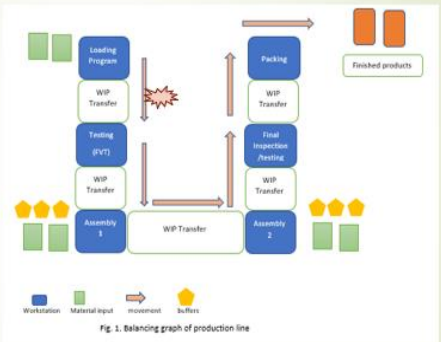


Fig. 1. Balancing graph of production line

Question 6

- "A new meeting for the lean workshop is conducted and the members comes with some suggestion, hear to their suggestions and reply to them"
- The student will hear to a recorded voice and a picture to the person coming with any suggestion.
- The effect of students' choices would be clear in the next question

Suggestion 1

- If the technologist is one of the members of the workshop, he will suggest combining the programs of ILP and FVT to one improved program that operates in just 50 sec.
- The goal: the separation of machine and manual time.
- By combining 2 programs together, we can get rid of redundant program start-up and connection times and will be able to reduce the number of stations by 1.

- accept

- reject

Question 7

- Students who have not chosen operators to be with the team, would receive a suggestion of including them. If they accept, they will receive the next question, if not, their records will be hardly reduced.
- One operator suggests a combination between assembly 1 and 2 workstations to one workstation and team has accepted the idea, stating that the workstation organization should be redesigned as an opportunity to eliminate waste. After a discussion the team suggested the 5s lean tool for the organization.
- The student is faced with unorganized work stations, with more items than required, without organization and unclean. The student should then use 5s lean tool. Th operation will start with selecting the items needed and assign an identification tag (red, yellow and green) to the items according to their importance in accomplishing the task (sort); choose the places where to store the items(setting in order); remove unnecessary items (systematic cleaning); find ways of turning these procedures standard (standardization).
- The student is introduced with a 2d picture of the two stations with some adjustable parts so that they can sort, remove and replace for getting the best result.

Suggestion 2

- If the logistic is one of the members of the workshop, he will suggest adding a conveyor belt to reduce the waste of the movement

- accept

- reject

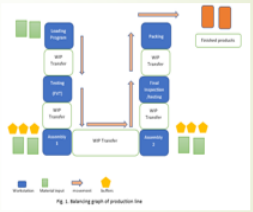
If this suggestion is accepted it will reduce your records by 3 since it cost the company while if rejected, the records are not changed. Actually, it is a "bad suggestion" and the effect of this choice would be clear in the next questions

Question 8

- Students are confronted different balancing graphs based on their answers to the different suggestions, The goal of this question is product flow optimization. The text of question 6 is:

"Try to eliminate waste operations by improving line layout, ergonomics"

- Students are provided the ability to change the balancing graph (change the position of the different boxes, rows and so on).
- A toolbar including different types of tools that students can use to optimize the line is available.
- Tools as (conveyor belt, Box hanger, hanging drill, drill, scanning glasses, labelling machine, upper and bottom controller housing with plastic parts and so on)
- Students are limited to use max 2 tools from the toolbar. Once clicked, the game askes(Are you sure that you want to select this item?), after agreeing, the tool is available to be used.
- Students have limited time to finish the job and once the time is out, the new cycle time and the new number of operators needed are calculated and shown on the screen. Based on this and comparing with the best approach, the records are updated



Suggestion 3

- If the shift leader is one of the members of the workshop, he will suggest having just one shift for producing this item for this period since the company is facing dramatic customer call-offs decrease. Discuss what effects the suggestion can lead to and reply to the suggestion:

-accept

- reject

If this suggestion is accepted it will increase your records by 3 while if rejected, the records are not changed.

Suggestion 4

- If the manufacturing planner is one of the members of the workshop, he will suggest looking at the ability to reduce waste/cost by redesigning the product. Discuss what effects the suggestion can lead to and reply to the suggestion:

-accept

- reject

If this suggestion is accepted it will increase your records by 3 while if rejected, the records are not changed.

Appendix C

Workstation 1:

Fixture machine: 

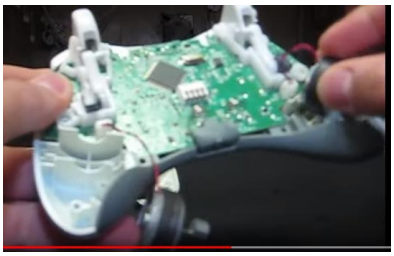
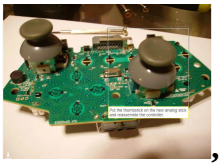
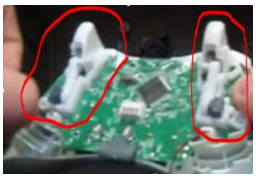
Circuitboard: 

Table 1. Operation process at the circuit board testing workstation

Task No	Operation Description	Operator	Machine	Operator Valueadded Activity	Operator Waste Activity	Cycle Time (1piece /batch)(s)
1	Open the cover, put the circuit board in the fixture machine and close the cover	X		x		7.70

2	Test and report results		X			
3	Observing and reporting the testing process	X			x	50
4	Open the cover and fetch the circuit	X		x		7.70
5	If the result is failing, the circuit board is moved to the debug workstation. And if it is passed, it is transported to the next workstation					6.3
				Cycle Time:		69.9

Workstation 2:

1. **Circuit board:**  **, like the one in the picture but without sticks.**
2. **Thumb stick:**  **, over**
3. **Analog:**  **, under**
4. **Motors:**  , under
5. **Triggers plastics:**  **under**

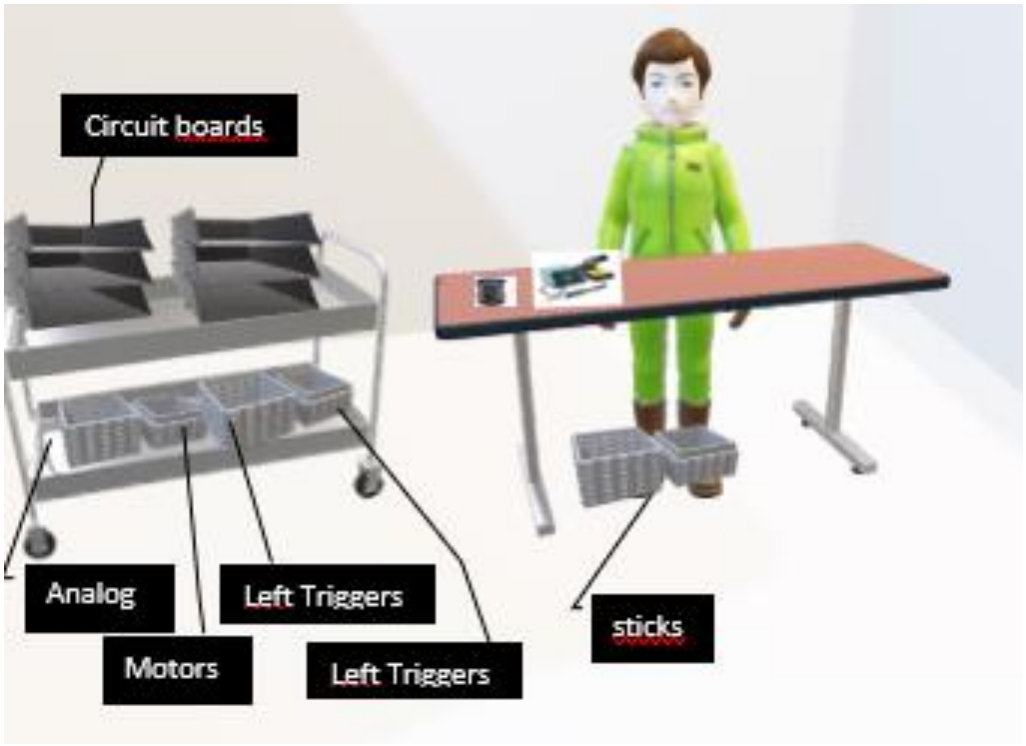
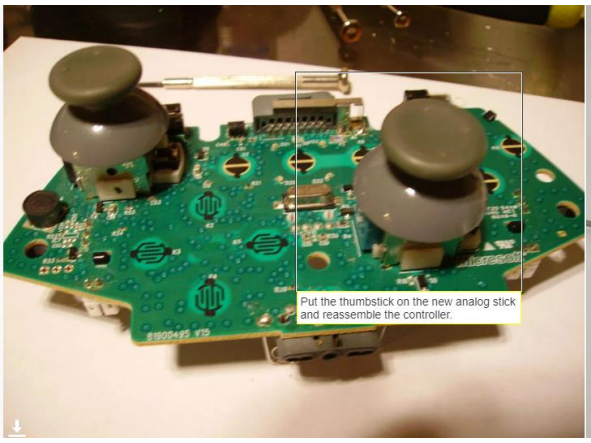
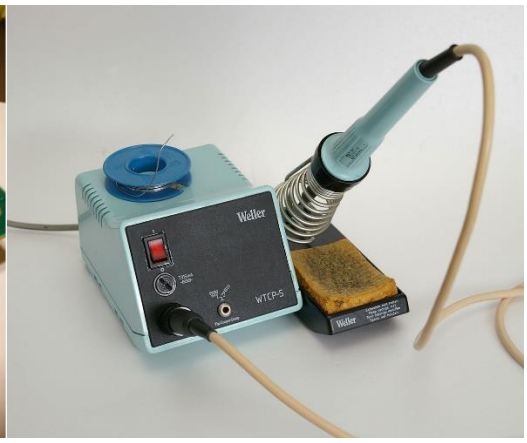


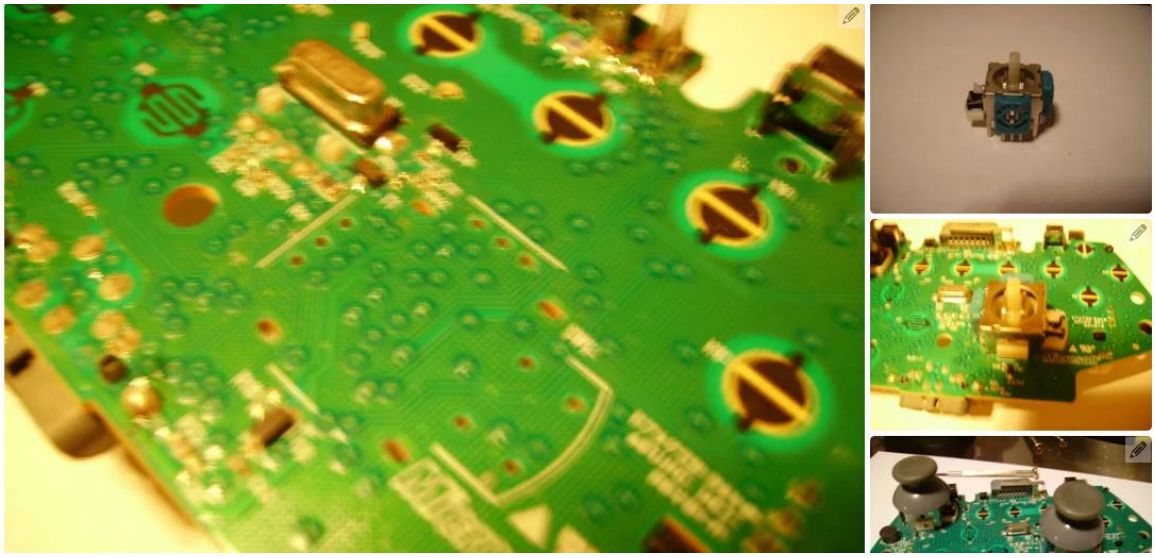
Table 2. Operation process at the soldering workstation

Task No	Operation Description	Operator	Machine	Operator Valueadded Activity	Operator Waste Activity	Cycle Time (1piece /batch)(s)
1	Pick up a tested circuit board from a buffer on a trolley and pick up two triggers plastics	X		X		7s
2	Solder the two triggers to the circuit board using the solder machine	X		X		60
3	Pick up two motors from a trolley 	X		X		4
4	Connect the wires of the motor to the					20

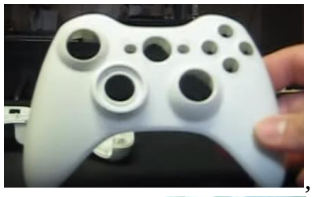
	plastics on the circuit board					
5	Pick up two pieces of analog 	X			x	4
6	In the other side of the circuit board, drop the analogs in theirs place and solder them.	X		x		50
7	Pick up two pieces of thumb sticks	X		X		3
8	Fix the thumb sticks to the analogs 	X		X		10
9	Cary the assembled circuit board to the next station					13
				Cycle Time:		171s

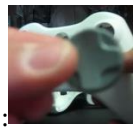




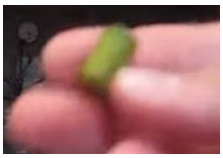


Workstation3:

A. The upper housing  , 

B. Directional pad front :   Back:  

C. Guide button  , back  , from a side 

D. Button: A  , back:  , from a side: 

E. Button: B 

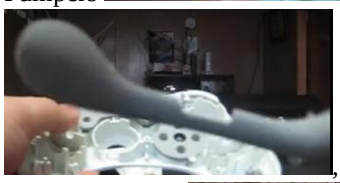
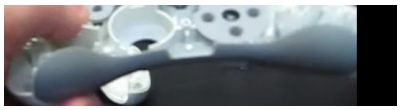
F. Button: X 

G. Button: Y 

H. The backing of the buttons: 

I. The backing of the direction pad: 

J. Pumpers 

K.  , 

L. Bottom housing,  , 

Table 3. Assembly 1 workstation

Task No	Operation Description	Operator	Machine	Valueadded Activity	Waste Activity	Cycle Time (1piece /batch)(sec)
1	Pick up an upper housing and the other buttons from a trolley and put them in a little box	X		X		25.00
2	Fix the buttons (their back and forth sides) and their gummy bases.	X		X		40
3	Fix the pumpers and the bottom side of the controller	X		X		20
4	Fetch a circuit board from the buffer and a bottom housing from a trolley					10
5	Fix the circuit board to the controller and at last put the bottom housing					30
6	Cary the assembled parts to the next station					6.30
						131.3

Workstation 4:

1: batteries.

2: battery cover.

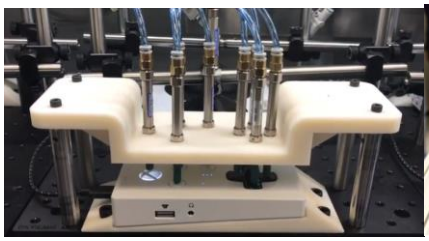
3. screws

4. screwdriver.

Table 4. Assembly 2 workstation

Task No	Operation Description	Operator	Machine	Valueadded Activity	Waste Activity	Cycle Time (1piece /batch)(sec)
1	Fix the 7 screws in the back of the controller.	X		X		85
2	Fetch batteries and a battery cover from a trolley				X	5
3	Locate batteries and put the cover			X		10
4	Transport the product to the next station's buffer				X	6.30
				Cycle Time		106.3

Workstation 5:

The testing machine:  

Task No	Operation Description	Operator	Machine	Valueadded Activity	Waste Activity	Cycle Time (1piece /batch)(sec)
1	Make a visual check	X		X		7
2.	Locate the controller in the testing machine,	X		X		10
3.	The machine tests the product and report the result		X			
4.	observe and report result	X			X	60
5.	Transport the product to the next station	X			X	6.3
						83.3

Workstation 6

1. Labelling machine
2. Protecting cover
3. Box
4. instructions book
5. cable
6. Keypad

Table 5. Packout workstation

Task No	Operation Description	Operator	Machine	Valueadded Activity	Waste Activity	Cycle Time (1piece /batch)(sec)
1	Walk to the labelling					4
2.	Label the product	X		X		10
3	Walk back to the packing workstation					4
4.	Pick up a protecting cover from a trolley	X			X	3
5.	fix the controller to the protecting cover and close it		a			10
6.	Pick up a box, instructions book, a cable and a from a trolley	X			X	13
7.	Put the instruction papers, cable and the product on the box	X		X		15
8.	Pick up a keypad from a trolley					7
9.	Put the keypad to the box and close it					10
10.	Scan the box					10
11.	Transport the product to the finished products trolley in the warehouse	X			X	20
				Cycle time:		106

Appendix D

John, Operation Director,
,stared in 2008

Julia, Administrative financial director,
,started in 2009

Maria, Manufacturing Planner
, started from 2009

Knut, Technologist
,started working in 2010

Rolf, Shift leader
, started working in 2010

Gøril, Logistic
, started working in 2019

Hans, human resources manager
, started working in 2010

Daniel, Quality Manager
, started working in 2019

Elisebeth, marketing and sales Director
, started working in 2019

Even, Operator
,started working in 2009

Jorunn, Operator/trainer
, started working one week ago

Joakim, Operator
,started working in 2011

Thomas, Operator/trainer
, started working one month ago

Ole, Operator
,started working in 2012

Anne, Operator

Yvonne, store employee
, started working in 2019

,started working in 2012

send

Appendix E

SUGGESTIONS BY EMPLOYEES.

Suggestion	The intended learning objective (section 2.1)	When Discussed	Accept/ Reject	**Cycle time**	**Budget**	Points
The company should invest in buying a conveyor belt that will connect all workstations together	waste elimination, resource allocation and decision making.	- "I agree, this would reduce the waste of the movement, Product will be every time taken from pallet to be processed and then placed back to proceed to the next station"	Accept	-38,2 s	80%	1
		- "I disagree, the money should be used more wisely"	Reject	-	-	4
		- "I disagree, it will take a large space"				
		- "I don't know"				
The company should reduce the nr of shifts to just one shift for producing this item for this period	Highlighting the overproduction problem and ways to get rid of it.	- "I agree, since the company has the problem of overproduction.	Accept	-69 s	-	4
		- "I agree, since the company have a necessity to reduce the line output"	Reject	-	-	0
		- "I disagree, due to the fact that the company could receive more demands if the cost of the product is reduced"				
		- "I agree, this would reduce costs related to electricity also"				
Creating multiple piece interprocess buffers instead of one piece so that each operator works with 5 pieces before transporting them to the next WS	Highlighting the concept of flow, waste elimination.	- "I agree, this would eliminate waste movement from one workstation to another"	Accept	-30,84	20%	0
		- "I disagree, this don't support one-piece flow required to reduce work in process"	Reject	-	-	4
		- "I don't know"				
The workstations labelling and packing, should be joined together to just one workstation.	Waste elimination.	- "I agree, this would eliminate movement waste"	Accept	- 8 s	-	4
		- "I disagree, I think this would make it difficult for the operator"	Reject	-	-	1
		- "I don't know"				
Reducing the number of screws used to fix a controller	waste elimination, product modification, resource allocation and	- "I agree, this will reduce the cost and the time.	Accept	-24 s	20%	4
		- "I disagree, this can affect the quality of the product"	Reject	-	-	1
		- "I don't know"				

	customer satisfaction.					
Fixing one screw in the middle of the controller instead of 7	waste elimination, product modification, resource allocation and customer satisfaction.	- "I agree, this will reduce the cost and the time used to fix 7 screws. - "I disagree, this can affect the quality of the product" - "I think that this should be discussed with the design department". - "I don't know"	Accept	-72,8	-	1
			Reject	-	-	4
Dropping out the testing workstation since only 2% of circuits fail the test yearly	waste elimination, risk management and customer satisfaction	- "I agree, the percentage is too low, and the time used in this station is worthy that the risk can be taken" - "I disagree, this can result in customer unsatisfaction. - "I agree, the failure would regardless be discovered in the final inspection station"	Accept	-69 s	-	4
			Reject		-	1
Dropping out the final testing workstation since too little products fail the test.	Waste elimination, risk management and customer satisfaction	- "I agree, the percentage is low, and the time used in this station is worthy that the risk can be taken" - "I disagree, this can result in customer unsatisfaction. - "I don't know"	Accept	-83 s	-	0
			Reject	-	-	4
Use scanner glasses instead of the normal scanner to reduce the space and the time used to do this operation.	waste elimination, resource allocation and decision making.	- "I agree, this would reduce the waste of the time" - "I disagree, the money should be used more wisely" - "I don't know"	Accept	-5 s	-20%	4
			Reject	-	-	4
Use a drill screwdriver instead of normal screwdriver to reduce the time used to do this operation.	waste elimination, resource allocation and decision making.	- "I agree, this would reduce the waste of the time" - "I disagree, the money should be used more wisely" - "I don't know"	Accept	WS4, op1 -40 s	10%	4
			Reject	-	-	0
Use a hanging drill screwdriver instead of normal screwdriver to reduce the time used to do this operation.	waste elimination, resource allocation and decision making.	- "I agree, this would reduce the waste of the time" - "I disagree, the money should be used more wisely" - "I don't know"	Accept	WS4, op1 -50 s	15%	4
			Reject	-	-	0

The company should alter the product mix by offering the product in two sizes and different colours to fit children and teenagers also.	waste elimination, product modification, resource allocation and customer satisfaction.	- “I agree, this would increase customer satisfaction, customers like new tastes”. - “I disagree, this will just make the process more complex without adding any value to the customer”. - “I don’t know”.	Accept		80%	4
			Reject			2
The company must try to improve the, appearance or quality of the product.	Kaizen, product modification, resource allocation and customer satisfaction.	- “I agree, the company should seek a way to exceed customer expectations, customers like new tastes”. - “I disagree, it is too risky, the relative high price of the product is the reason for the decreased demand, we don't have to do anything but cutting the prices”. - “I disagree, it is not the right time for making changes, the given resources should be used to eliminate waste at first”	Accept	-	80%	4
			Reject	-	-	2
Since the number of the complains are very low, this means that our customers are satisfied, and I don’t suggest analysing the reasons for the reduction of demand more carefully. This would be waste of time and money	waste elimination, product modification, resource allocation and customer satisfaction.	- “I disagree, the number of complains don’t show the real picture” - “I agree, the relative high price of the product is the reason for the decreased demand, we don't have to do anything but cutting the prices”. - “I don’t know”.	Accept	--	-	0
			Reject		-40%	4
Use forklifts to move the finished products to the store.	waste elimination, resource allocation and decision making.	- “I agree, this would reduce the waste of the movement” - “I disagree, the money should be used more wisely” - “I don’t know” - “I disagree, they take up space and are dangerous.”	Accept	WS 6, Op 11, -20	50%	0
			Reject	-	-	4
Add new feature to the product	Kaizen, product modification, resource allocation and customer satisfaction.	- “I agree, the company should seek a way to exceed customer expectations, customers like new tastes”. - “I disagree, it is too risky, the relative high price of the product is the reason for the decreased	Accept	-	40%	2

		demand, we don't have to do anything but cutting the prices". - "I disagree, it is not the right time for making changes, the given resources should be used to eliminate waste at first"	Reject	-	-	4

Appendix F

The required Feedback for the different suggestions.

The suggestion	The needed information
Reducing the number of screws used to fix a controller	"it is possible to reduce the number to 5 screws without reducing the quality of the product, but the process of improving the product needs some time and cost". "I need two days to find the right information about the estimated cost for you"
Fixing one screw in the middle of the controller instead of 7	"The number of screws can be reduced but I don't think that one screw is enough". "I need two days to check the right number for you" "I need just two days to find out about the number of screws that can be reduced without any problem"
Dropping out the testing workstation since only 2% of circuits fail the test yearly	"I agree, the failure would regardless be discovered in the final inspection station" "However, I am not sure about the authenticity of the information that only 2% of circuits fail the test yearly, give me just one day and I will check this for you"
The company must try to improve the, appearance or quality of the product.	"Actually, there is a feature that all customers use and like, and I see opportunity to add significant value to it" "If you can give me two days, I can discuss this feature with my boss and send you more information about the possibility of improving it"
Add new feature to the product	"Actually, there is a new feature that can be added but I am not confident it will be valued." "If you can give me two days, I can discuss this feature with my department and send you more information about the possibility of adding it"