LEAN SIX SIGMA GAME APP FOR ANDROID

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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LIST OF ABBREVIATIONS

SMED   -   Single Minute Exchange of Dies

MIT   -   Massachusetts Institute of Technology

TIMWOOD   -   Transportation, Inventory, Movement, Waiting,

                         Overproduction, Over-Processing, Defect

VA   -   Value Added

NVA   -   Non-Value Added

VSM   -   Value Stream Mapping

SME   -   Small and Medium Sized Enterprises

MSF   -   Microsoft Solutions Framework

SEG   -   Serious Educational Game

RPG   -   Role-Playing Game

2D   -   Two-Dimensional

3D   -   Three-Dimensional

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ABSTRAK

Banyak industri telah melaksanakan konsep "lean" dalam barisan pengeluaran. Pengetahuan "lean" dapat diajar dengan lebih efisien jika menggunakan permainan simulasi dan bukannya cara pengajaran yang tradisional. Objektif utama kajian ini adalah untuk mencipta permainan Android yang memperkenalkan konsep "lean". Perisian yang berbeza telah dicuba untuk mengetahui perisian yang paling sesuai untuk digunakan dalam kajian ini. Unsur-unsur pendidikan dan hiburan pada aplikasi yang sedia ada telah diperhatikan. Perisian yang telah dipilih untuk mencipta permainan Android adalah "MIT App Inventor". Dalam kajian ini, sejumlah empat konsep dipilih untuk dibentangkan dalam permainan. Konsep-konsep dipilih adalah 5S, "Visual Management", "Single Minute Exchange of Die (SMED)" dan simulasi barisan pengeluaran. Penilaian permainan dijalankan untuk mengetahui pendapat orang ramai selepas permainan diciptakan. Permainan diberikan kepada 10 pengguna. Maklum balas diterima dan keputusan penilaian telah dianalisis. Orang yang mempunyai pengetahuan asas "lean" akan meningkatkan pengetahuan mereka selepas bermain permainan ini. Permainan yang dicipta menghiburkan dan juga memberi pengetahuan kepada pemain. Malah pemain yang tidak mengetahui konsep "lean" juga akan memahami konsep-konsep yang telah dikatakan tadi.

ABSTRACT

Many companies implement lean concept in their production line. Lean knowledge can be transferred more efficiently by using simulation game instead of traditional teaching method. The prime objective of this study is to develop Android games which introduce the lean concept to someone new to the concept as a form of gamified training. Different software has been explored for the most suitable software to be selected as the application platform. Elements of educational and entertainment of the currently existing application are observed. The software which is chosen to develop Android game is MIT App Inventor. For this study, a total of four concepts of lean is chosen to be presented in the game. The concepts are 5S, visual management, Single Minute Exchange of Die (SMED) and simulation of production line. After the games are developed, evaluation of the games is conducted to obtain user opinions. The games are given out to 10 users to be experienced. Feedbacks are received and results are analysed. People with basic lean knowledge can play the games to further enhance their knowledge. The games are both educational and entertaining. Even people who do not have knowledge in lean will be able to grasp the basic knowledge of the mentioned concepts.

CHAPTER 1: INTRODUCTION

1.1 Overview

Nowadays, lean concept is frequently applied in a company. Lean is a systematic method for waste minimization without sacrificing productivity (What is Lean?, 2017). Waste includes all activities which do not add value from the perspective of customers (Zhang and Chen, 2016). Value is any action or process which customers will pay for willingly. Lean maximizes customer value while minimizes waste. Waste consumes resources but does not add value to the product (Bhim et al., 2010). In other words, implementation of lean concept provides more value for customers with less resource. The final aim is to provide perfect value to the customer through a perfect value creation process that has zero waste.

Lean is a concept which focuses on waste elimination within a manufacturing system without sacrificing productivity. It is also a management philosophy that encourages a culture of continuous improvement to maximize value and minimize waste (Jiunn-Chenn et al., 2011). The direct benefits of lean concept are reduced operating lead times through the action of removing non-value-added steps and reducing operating costs (Bhim et al., 2010). Lean focuses on elimination of seven wastes which are known as TIMWOOD (Transport, Inventory, Motion, Waiting, Overproduction, Over-Processing and Defects) (El-Kateb et al., 2015).

People increasingly recognize its benefit and try to implement it into the industry. Some companies even have a specific department for continuous improvement using lean concept. A lean organization understands customer value and focuses its key processes to continuously increase it.

It is the best that everyone in the company has basic knowledge of lean. Then, they can implement action directly into their job scopes using knowledge of lean. They could find out the solution for obvious flaw. For example, the leader of a production flow can

analyse the flow and figure out the bottleneck. Then, actions such as combining or splitting task could be taken to increase throughput. The flaws which is hard to be seen require attention from the department of lean. With every employee gaining lean knowledge, the burden of lean department will be lessened and productivity will increase.

However, lean concept should not be taught solely with conventional training. It will be boring and the learner will quickly be losing interest. Lean concept should be taught with simulation game. Through the game, then the learner will gain interest and acquaint with the concepts easily. Many simulation games with instructions are available either in book or Internet. Some even have the materials ready to be printed out.

In this project, few Android training games are to be developed. The purpose is to introduce lean concept to people through the fun way. The players shall gain Lean Six Sigma knowledge from each session of the game. From this fun game, all individuals include people with zero knowledge of lean concept in mind will be able to grasp the basic concept of lean. Through the development of this game, it will be more convenient for people to learn lean as no material is needed to be prepared beforehand.

1.2 Objectives

To design and develop at least three educational and training games platform for someone to acquire different Lean Six Sigma knowledge

1.3 Problem Statement

Lean Six Sigma is useful in an organization as it can always improve the quality of product or process by eliminating waste. However, the concept is still not widely known by the people. In some cases, it is not known by engineers working in factory. Thus, the main objective of this project is to promote Lean Six Sigma knowledge in a fun and simple way. The Android training game will be more interesting and convenient as it does not require advanced preparation as only an Android device is needed.

1.4 Scope of Project

In this project, general knowledge of Lean Six Sigma will be studied. Four specific lean concepts are selected. An Android game will be developed for each lean concept. The games will include various stages and explanation. Explanations such as real-life scenario and advantages of applying the specific concept will be presented. Knowledge regarding the specific lean concepts is introduced to users no matter they are first-timer in this lean concept or had basic knowledge on Lean Six Sigma. The games will be both educational and entertaining.

CHAPTER 2: LITERATURE REVIEW

2.1 Lean Manufacturing

Lean concepts are mostly coming from Japanese industry. Lean thinking surfaced initially with the development of the Toyota Production System, which Taiichi Ohno and associates structured to help a company called Toyota to survive in a condition of capital and resources constraints due to warfare (Galdino et al., 2017). Lean manufacturing is a technique of waste elimination. By waste reduction, it maximizes value of product through opinion of customer. Value Added activity (VA) and Non-Value Added activity (NVA) are sorted (R.Sundar et al., 2014). NVA Wastes are Transportation, Inventory, Motion, Waiting, Overproduction, Over processing and Defect (R.Sundar et al., 2014). The wastes come in short form of TIMWOOD (El-Kateb et al., 2015). In such a competitive environment, applying lean manufacturing techniques to the company is the best choice. The benefits include: cost reduction, increase in output and decrease in lead time (Nguyen and Do, 2016).

Both lean manufacturing and six sigma methodologies are used worldwide. Companies have to understand crucial factor to successfully implement both methods. Lean manufacturing targets to reduce waste while six sigma targets to reduce process variations (Alhuraish et al., 2017). There are many factors which affect whether the implementation of lean manufacturing and six sigma is successful, which include: top management commitment and support, education and training, communication, involvement of employees and cultural change (Alhuraish et al., 2017).

Lean tools play important role in supporting knowledge creation and performance in lean construction (Zhang and Chen, 2016). Lean construction means the application of lean principles to companies. Some of the famous lean tools are explained. Value stream mapping (VSM) is the process of mapping the material and information flows which are used to monitor the activities done by manufacturers, suppliers and distributors to deliver product to customer (Rahani and al-Ashraf, 2012). VSM is utilised to assess

current manufacturing process from start to deliver to customer and create future ideal state processes (Venkataraman et al., 2014). VSM involves all activities including value-added and non-value-added. It is a visual tool to help us see the hidden waste and source of waste (M. Goriwondo et al., 2011). By observing the production flow, the process which is currently done is illustrated in Current State Map. Then, Future State Map is drawn to identify the root causes of waste and solutions can be found through discussion. VSM benefits the organization as it reveals hidden waste that affected the productivity of production line. Majority of time is wasted on waiting and non-value-added activities. With VSM we can compare between current state and future state of production line (Rahani and al-Ashraf, 2012).

Takt time is the rate at which a finished product needs to be completed in order to meet customer demand. Bottleneck is the process which requires the longest cycle time in the production line (R.Sundar et al., 2014). Cellular manufacturing is model for workplace design and it is based on fundamentals of Group Technology which seeks to take full advantage of the similarity between parts, through standardization and common processing (V.Anbumalar et al., 2014). The layout is often arranged in U-line. Advantages of applying cellular manufacturing are reduction in lead time, setup time and work-in-process inventories (Bansee and V. Chowdary, 2007). Line balancing is levelling workload among all the processes in a cell or value stream to remove bottlenecks and excess capacity (Kumar and Mahto, 2013). In pull system, components are only replaced when they are consumed so companies only make enough product to meet customer demands. This will eliminate excessive inventory and prevent people from overwork. Kanban is a visualization tool that ensure the flow of work is optimized (R.Sundar et al., 2014).

To achieve waste reduction, lean manufacturing is implemented. In small and medium sized enterprises(SME), leader is very important as he holds the element of decision making. Conflicts are bound to happen as there is lack of methodology and formal procedures. Leader should also be able to motivate employees in contributing. Employees training are important as talents are often lacking in SME (A.Moeuf et al., 2016).

In case study of sheet metal stamping subassembly area, the company has found that lean manufacturing principle is a good improvement concept which is used to eliminate

waste and non-value-added activities. It also can maximize competitive advantage. This case study investigates about how applying lean manufacturing can improve work efficiency. Processes are studied in detailed by observation. Process flow diagram is drawn. Root causes are determined by using cause and effect diagram. Deburring and polishing process is seen to create the most non-value-added activities. Lean tools and techniques such as visual management and 5S are applied. After implementing lean principles, processing time and non-value-added activities are greatly reduced. Another result we got is that lean tools do not necessary require high cost technology and investment. Employees should work and create continuous improvement together (Choomlucksana et al., 2015).

2.2 Lean Training and Game in Industry

Since many companies realise the importance and advantages of applying lean manufacturing, they provide training to their employees. Simulation training includes from small scale training (paper-based) to larger scale training (push car assembly). Low cost resources such as paper and stickers are preferred. This is to ensure the session is easier to be replicated by other trainer. Sessions of lecture, workshop, simulation and discussion is held (Brioso, 2015). Different simulation game has different aim to be achieved. Teaching lean with formal instruction such as powerpoint presentation will be boring and hard to be grasped. So, concept of simulation game and training is introduced. Training is given to employees to deepen their knowledge and understanding on lean concept (De Vin et al., 2017). However, the training field should realistically resemble to a real industrial environment. In the training game, the difficulty has to be controlled. If the task is too easy, the participants will be bored. If the task is tedious, the participants will feel discouraged.

Most simulation game has similar model as shown in Figure 2.1. A situation is given in workplace. Manufacturing line is simulated. Properties such as processing time and breakdown interval can be set. Mobility is enhanced as physical layout of workstation is to be adjusted according to the liking of industrial worker. Participants are given role to play. Rules are briefed. Then, first round is played. After the game is played for a certain amount of time, the game is stopped. Participants will have a discussion session to discuss about improvements which could be made to improve the productivity in

simulation game. Improvements are made gradually after few rounds (De Vin et al., 2017).

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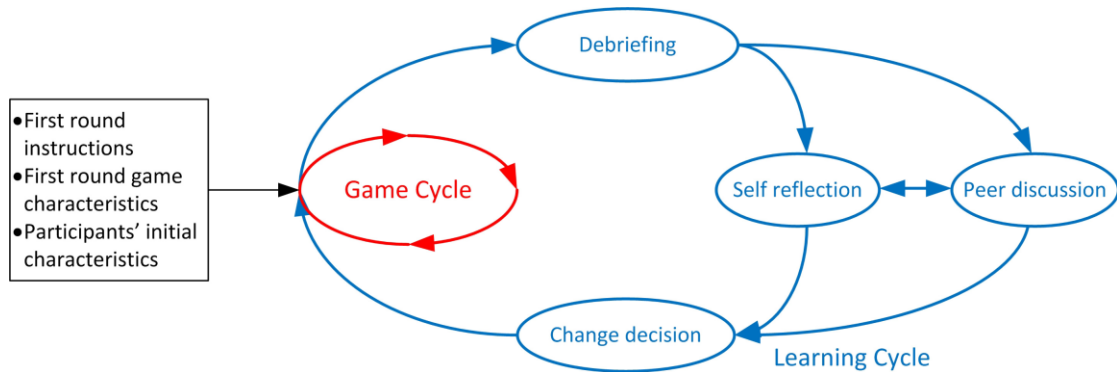
Figure 2.1: Model of game-based learning

(De Vin et al., 2017)

Many lessons can be learnt through the game. The main learning point is learning the differences between traditional method which is mass production system and lean production system (J. Blochl et al., 2017). Lean concept such as 5S, visual management and Kanban system will be incorporated into the game. Participants can learn and visualise the benefits of lean concept. Layout can be changed easily in the game so this ease them to experiment on different layout such as u-shaped and job-shop layout. Takt time is recorded and reduced as much as possible. Quality in a leader will also be reconsidered as traditional leadership style is not suitable anymore. Leaders have to involve more in the process and know the current situation exactly to improve the production line alongside with the team (De Vin et al., 2017). Also, through the simulation game, trainees are taught to be persevere and do not give up easily when improvements do not show the expected result.

In a case study, the Pull Competence Centre opened up a learning factory for application-related research and education purpose. Students and companies use this learning factory as a simulation game with educational purpose. Simulation game which focuses on material flow integrated with elements of Industry 4.0 is developed. Main aim of this game is educating production logistics planner about Lean and Industry 4.0. There are many rounds in the game. Production variant will increase with every round.

Solutions are proposed to solve the problem in simulation. There is assessment after each round and advice is given by trainer. Survey is also given to participants to evaluate challenge in logistic planning (J. Blochl and Scheneider, 2016).

2.3 Software development

In these days, Android device is becoming more and more popular. Technology is improving starting from 2000. Gaming industry also rises alongside technology development. Android device such as mobile phone, tablet and computer are used often. It has slowly becoming an important part of people's lives (Muharum et al., 2017). According to a research on 2014, 59% of American play video games while 51% of United States households own at least one type of game console (D. Gallagher, 2014). Many people love to play game on mobile devices to cure their boredom. Game is an activity which is suitable for everyone. Games also has other benefits such as brain development, problem-solving, improve concentration, train speed, and others (Kurniati et al., 2015).

Software engineering field has been receiving positive evolution for the past few years. This field require different teaching and learning method. To acquire standard of game design, relationship between game design pattern and teaching and learning function has to be figured (H. Flores et al., 2016). However, software engineering experiments consist of complex concepts, procedure and objects (Solari et al., 2018).

A case study shows the complete software development life cycle and writing challenges based on experiences of student. Different organization uses different languages when developing software. One of the framework introduced to the students is called Microsoft Solutions Framework as shown in Figure 2.2. MSF combines concepts from traditional waterfall and spiral models (D. Ballentine, 2015).

Figure 2.2: Model of MSF

(D. Ballentine, 2015)

Second model introduced is Co. Both model has the similar concept. Vision is determined. Co model and MSF are very capable tools. Then, students have to choose which software are they going to use to build their game. A free and open source software called Quest is chosen. It is a good choice as it has the ability to build a competent game while having system which is not too complex. During beginner stage, student should focus on the story instead of graphic. Throughout the semester, students have to develop playable game and prepare final reports. When students face problem in developing their game, they can always ask help from their instructors (D. Ballentine, 2015).

RPG game can also be created using software development software. It is one of the most widely used game form. RPG has been the subject of rapidly increasing interest among game community (Drachen et al., 2009). However, game is not necessarily in 3D in order to attract player. If it has a good gameplay, even 2D graphic could make a good game. Players can gain more knowledge from playing 2D educational game compared to a complicated game which is too realistic (C. Koops et al., 2016). A game which can function without the need of network is more convenient. It is the best that if certain skill such as quick thinking and resource management can be trained through playing game. Educational game is much more preferred (Kurniati et al., 2015).

Aside from playing games using software, apps can also be used as different function. Apps can be advertisement platform which can generate high return and interest. It can also be used as marketing tools. For example, free or low cost apps can be used to

promote related industry. It can be a door to open up to the public about the certain industry. Apps can also be used to replace the existence of certain physical objects such as library or museum. Also, software application can be used to assess health condition of patient. A digitally enabled heart failure management platform with medical digital tool and software solutions is developed (Talmor et al., 2018). Digital information is combined with images from real world. When label on a bottle is scanned with mobile devices, information regarding the bottle can be retrieved quickly (J.Williams et al., 2011).

There are many challenges for using apps on mobile devices. Spaces on mobile devices are limited so information has to be adjusted to fit into the one screen. Also, since the apps are gotten online, it will be hard to find financial support online. We also have to be careful regarding the information because it can be stolen easily. Even after software is developed, software testing is required. The application has to be verified and validated to make sure it meets business and technical requirements (U. Farooq, 2010).

2.4 Learning with Interactive Game

Gamification is application of game design element and game principle in non-game context such as business and education. It is an implementation of game elements in serious situations such as social problems (Vanolo, 2018). It improves participants' motivation and performance when carrying out a certain task. Tedious task is applied with game-like elements into the design of user interface of software (Kasurinen and Knutas, 2018). With the game, the player can be motivated to learn new skills. The aim is to propose a complete framework for gamification in software engineering. The framework consists of three elements (Garcia et al., 2017):

1. Ontology: ontology contributes a set of concepts for gamification
2. Gamification methodology: methodology contributes step-by-step process for gamification
3. Support tool: support tool ease organization to gamify their tools

The proposed framework is applied in a real software company. Background, design, subjects and analysis units, field procedure and data collection in this case study is investigated. This methodology has helped the company to integrate gamification

culture into the work environment. The company focuses on two points which are business objective and player analysis. This method also adds "fun" element into the work as employees can access their own activity in gamified environment (Garcia et al., 2017).

Knowledge will be learnt easier through interactive game compared to textbook. App comprises education material and entertainment is preferable. The players can learn while still be entertained (Ar Rosyid et al., 2018). Serious Educational Game (SEG) is an alternative learning method to provide effective experience during learning process. Game elements are infused in game. The final goal is to enhance learning and entertaining experience (Ar Rosyid et al., 2018). Many users will find this learning method easier.

Interactive computer game is also suitable for children in their developing stage. Visual presentation is very important when transferring knowledge to children since 70% of sensory receptors in human body are in the eye (Hsien-Cheng et al., 2017). Survey is done among parents of children. Game gave usefulness and playfulness. Digital game-based learning system sure brought satisfaction to users and they will continue to use the app to enhance the knowledge of the children by playing it repeatedly. While game-based learning may give the same amount of knowledge to users when compared with non-game-based learning, it definitely gave better experiences to the users as it brings more fun. A third type of learning method may be introduced in the short future which is virtual reality (Chi-Cheng et al., 2017). Environment can be simulated more concisely.

Video game may also help to develop skill of users such as communication, resourcefulness and adaptability (Barr, 2017). Game with 3D gameplay may also provide knowledge in a clearer way. In a case study, a game named Diabetes Visualizer's is developed to deepen medical knowledge of users. Software tools are presented to assist the management of diabetes. The project studies on ability of human-computer interface to monitor diabetes level of user. 3D interactive gameplay give insight to user about complex medical data. User can have a view within blood vessels and observe changes in blood sugar level as shown in Figure 2.3. Results show information is passed on better with 3D presentation compared with 2D design. Information regarding insulin and blood sugar can also be obtained (Patterson, 2014).
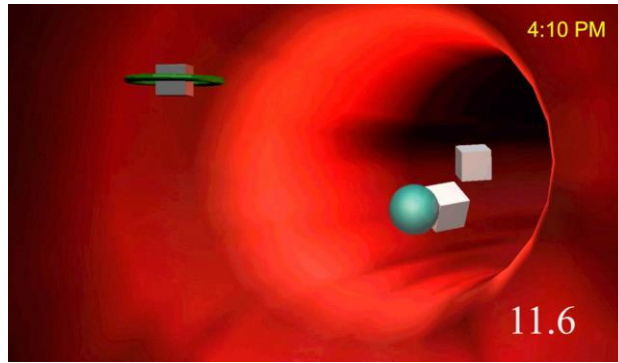
Figure 2.3: Gameplay that shows blood vessel

(Patterson, 2014)

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction

In a study, a well-planned methodology was essential to ensure the effectiveness of the research and also to ensure the study to be a success. This study will be carried out to investigate method to build few applications which can successfully promote the concept of lean. The software development framework was shown in Figure 3.1.

Firstly, software was selected to be used as a medium to develop the games. Four lean concepts were selected to be incorporated in games. The software was familiarized with. The tools used which were called components and blocks were studied and experimented with. Limitations of the software were identified. Stages and explanation of each game were planned. The games were conceptualized. Then, they were built with selected software. The game was connected to Android device via Wi-Fi to enable real-time testing. Changes made on software were shown on Android device immediately. Games were installed to Android device. With this instalment, the game was permanently on the device. Games were tested and improvement was done. After the game was finalised, games and survey questions were distributed to ten users to obtain public opinion on developed games.
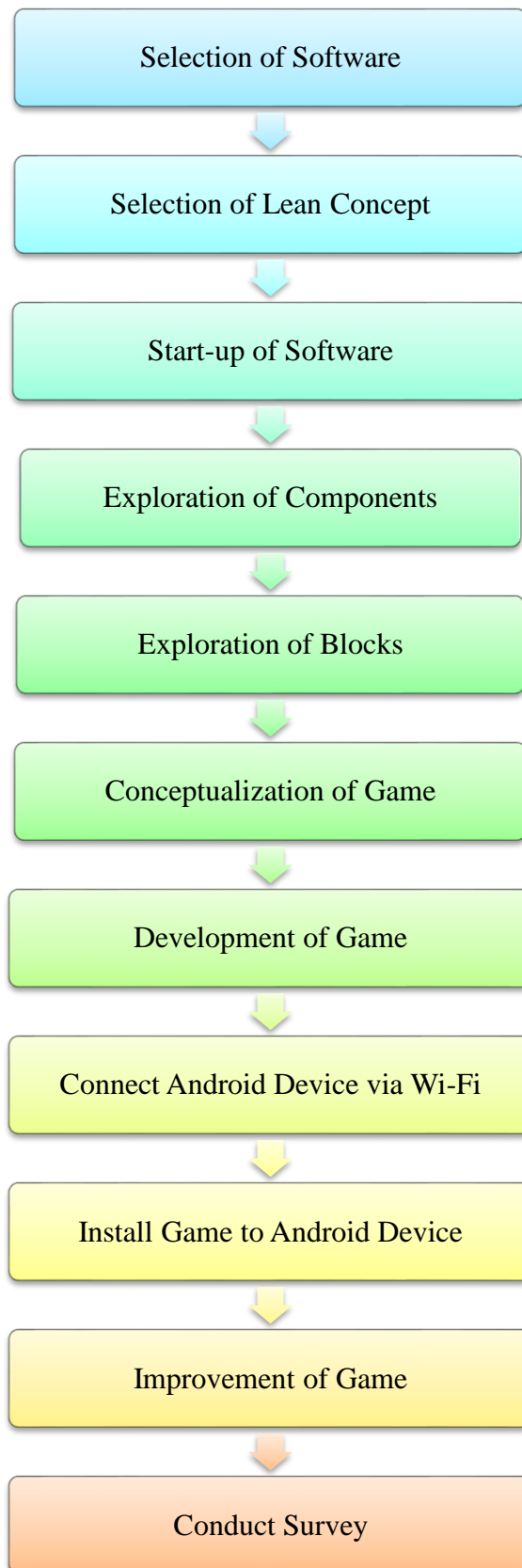
Figure 3.1: Software development framework

3.2 Selection of software used to develop games

Firstly, the suitable software used to build the game was determined. Researches were done to compare between the software of game development. Since the main goal of the game was to promote lean concept by gaming method instead of reading, the game to be built was more towards the aspect of educational. Hence, the game should not be too complex. The game should be simple enough for everyone to play and understand. Amount of wordings should be more than the typical game since explanation was needed to justify the reason behind the concept. After researching for the software available, the choices for software of game development was narrowed down to three choices which are MIT App Inventor, Stencyl and Unity 3D.

3.2.1 MIT App Inventor

Google provided an open source application which can be operated through the web. The application is called MIT App Inventor. Now, this application is maintained by the Massachusetts Institute of Technology. Hence the name of MIT. It allowed even beginners in computer programming to develop software applications for the Android system (Hardesty, 2010). It operated on graphical interface that allows users to drag-and-drop visual objects. No complicated coding was needed. The simplicity of the system encourages people to brainstorm idea and the idea can be illustrated with ease. Logo of MIT App Inventor was shown in Figure 3.2

Figure 3.2: Logo of MIT App Inventor

(MIT App Inventor, 2017)

3.2.2 Stencyl

Stencyl is a game development software. It is used to develop 2D games for many devices such as computers and mobile devices. The software was free to be downloaded. Originally, the software was called "StencylWorks" while in development and for initial release. The name was later shortened to just "Stencyl". This software was considered one of the easiest tools for game development. Logo of Stencyl was shown in Figure 3.3.

Figure 3.3: Logo of Stencyl

(Stencyl, 2017)

3.2.3 Unity

Unity Technology constructed a useful game engine which is called Unity. It could be used to develop both three-dimensional and two-dimensional games or simulation. The developed application could be played on computer, consoles or mobile devices. Coding was needed to develop software using Unity. It was written in C++ or C#. Logo of Unity was shown in Figure 3.4.

Figure 3.4: Logo of Unity

(Unity, 2018)

3.2.4 Comparison

Table 3.1: Comparison between three possible software

	MIT App Inventor	Stencyl	Unity
Download required	✗	✓	✓
Drag and drop feature	✓	✓	✗
Coding required	✗	✗	✓
Real-time function testing	✓	✗	✗
3D	✗	✓	✓
2D	✓	✓	✓
Android platform	✓	✓	✓
Difficulty	Low	Medium	High

3.2.5 Final choice

Different aspects were compared between three game developer. MIT App Inventor was chosen due to its user-friendly aspect which allows users to drag-and-drop easily. The feature of "what you see is what you get editor" was very convenient. Real-time function testing allowed users to observe result immediately and detect mistakes efficiently. All games were developed in two dimensional, so this software met the demand. The difficulty was not high and could be learnt quickly.

Final choice: MIT App Inventor

3.3 Selection of lean concept

Lean concepts were studied to find out which concept and knowledge was the simplest and easiest to be represented and understood through simple game.

The 4 concepts selected were:

    i.   5S
   ii.   Visual Management
  iii.   SMED
  iv.   Simulation of Production Line

3.3.1 Concept 1: 5S

5S was a system used to organize workspace so that work can be performed efficiently, effectively and safely. It is a basic lean tool for variation reduction, the establishment of consistent standards and visual management (Bicheno, 2015). Five Japanese words were used: *seiri, seiton, seiso, seiketsu* and *shitsuke.* In English, those words were translated to Sort, Set In Order, Shine, Standardize and Sustain (Veres et al., 2017). In this five-step process, each S represented one part that could improve the overall business. All types of business would benefit through the implementation of 5S. Clear presentation of 5S was shown in Figure3.5.

Figure 3.5: Visual presentation of 5S

(What is 5S?, 2018)

Each S is explained in below (5S, 2018; Veres et al., 2017):

1. Sort (Seiri)

All the tools or material should go through differentiation between necessary and unnecessary. Unnecessary item should be thrown out and necessary item should be remained. Aspect of the item such as purpose, last usage and frequency of usage could help in identifying necessary item. The workspace will be more organized if unnecessary item were got rid of.

2. Set in order (Seiton)

All the tools and material remained should be arranged in a logical way. Aspect of item such as frequency of usage and path of worker takes to obtain the required item are considered before arranging. Items should be able to be found in a short time without causing a lot of waste.

3. Shine (Seiso)

This step was the step which is the easiest to be overlooked. The workplace should be cleaned regularly. The actions included sweeping, mopping and putting item away. Regular maintenance was required for machinery and equipment as they were the most important asset in business. Problems stood out easily.

4. Standardize (Seiketsu)

This step was extremely important to maintain all the efforts made by first three steps. Rules and standard were set for workplace to prevent the condition reverted to previous condition. Checklist or chart were useful. Everyone should be reminded of their daily task continuously.

5. Sustain (Shitsuke)

This step was about making 5S a long-term program. The actions above should not be taken as temporary action. It should be made as habit of everyone in the organization. Follow up should be done by manager to make sure the actions implemented above were maintained.

3.3.2 Concept 2: Visual Management

Visual management is a concept with the goal of making situation to be understood easily by only taking a glance at the place (Visual Management, 2018). The user should grasp much information as possible in the shortest possible time as possible. This concept can increase effectiveness of communication and reaction (Visual Management, 2018). It should take interesting and non-written approach to convey the message to people. It can be done with the help of 5S. This approach can contribute to better controlling of performance within the complexity of the new environment in production flow (Steenkamp et al., 2016).

3.3.3 Concept 3: Single Minute Exchange of Die (SMED)

SMED is the abbreviation for Single Minute Exchange of Die. It is one of the methods used in production line to reduce waste. It is a series of concepts and techniques used for reducing changeover time until it is eliminated. Firstly, the elements are classified into internal or external operations. Then, internal elements are changed to be done externally. Time needed to complete an internal task is reduced as much as possible. Internal operation means task done during operation and will stop the production while external operation means task and work which are done during changeover. The waste elimination principle is to minimize NVA and shift our focus on VA activities (Al-Akel et al., 2017). The aim of SMED is reducing setup time from hours to less than 10 minutes. Hence the name of single digit (SMED, 2018). 5 steps of SMED include:

1. List all the steps of a "changeover"

2. Identify internal and external operation

3. Transfer internal operation to external operation

4. Decrease time of internal operation

5. Decrease time of external operation

Advantage of implementing SMED:

- Lower manufacturing cost

- Lower inventory levels

- Smoother start-up

- Quick to react to customer demand

3.3.4 Concept 4: Simulation of Production Line

A sequential line of workstation is simulated to provide experience for users. Customer demand will vary such as in reality. Limited time is given before customer turn away. Freedom is given for the user to choose which product they are going to produce.

3.4 Start-up of MIT App Inventor

To have access to MIT App Inventor, two things were absolutely necessary: Internet and Gmail account. Gmail account could be made easily without any payment required. In a web browser, link: http://appinventor.mit.edu/explore/# is opened. "Create apps" as shown in Figure 3.6 was clicked.
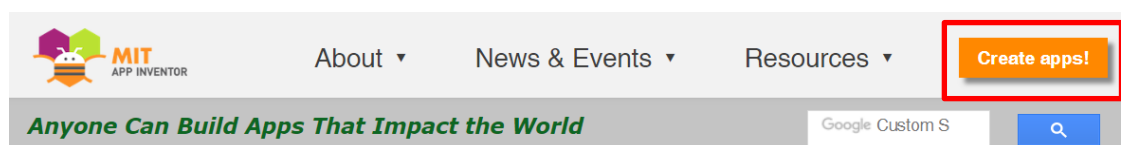
Figure 3.6: "Create apps!" was clicked

After clicking, the web browser will be directed to the new webpage. A name must be given before creating a new project. The browser was divided into 4 columns. There was a list of components to be chosen on pallete in Column 1. In Column 2, initial screen called Screen 1 will appear. In Column 3, components chosen are listed and they can be renamed by user to avoid confusion. Properties of each tool were shown in

Column 4 after selecting the specific tools in Column 3. Aspects of tools could be adjusted according to user.

MIT App Inventor was divided into 2 parts which were *Designer* as shown in Figure 3.7 and *Blocks* as shown in Figure 3.8. In *Designer,* tools were selected. In *Blocks,* behavior of components was set.
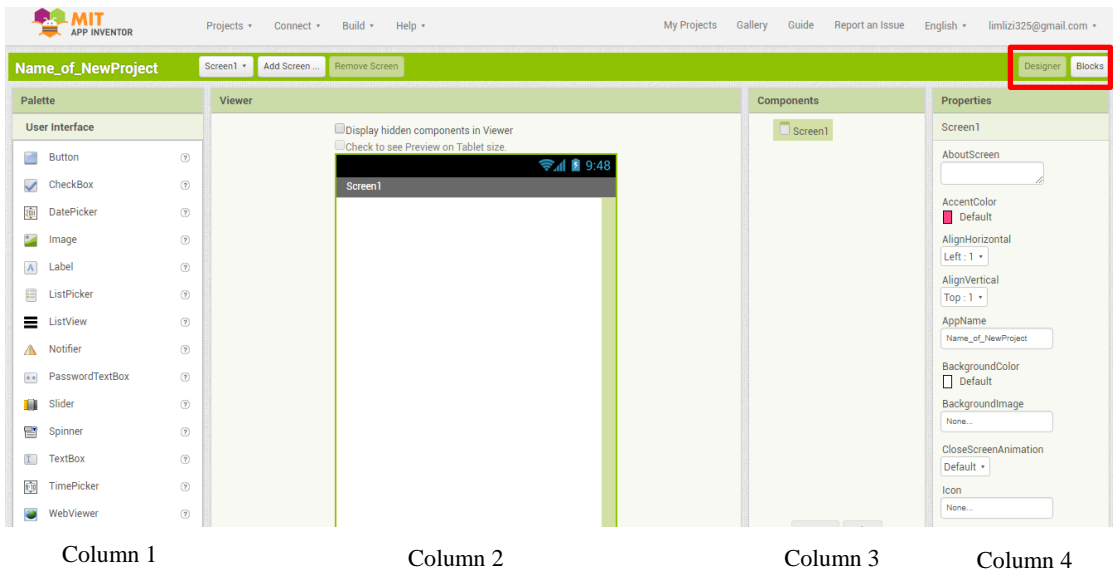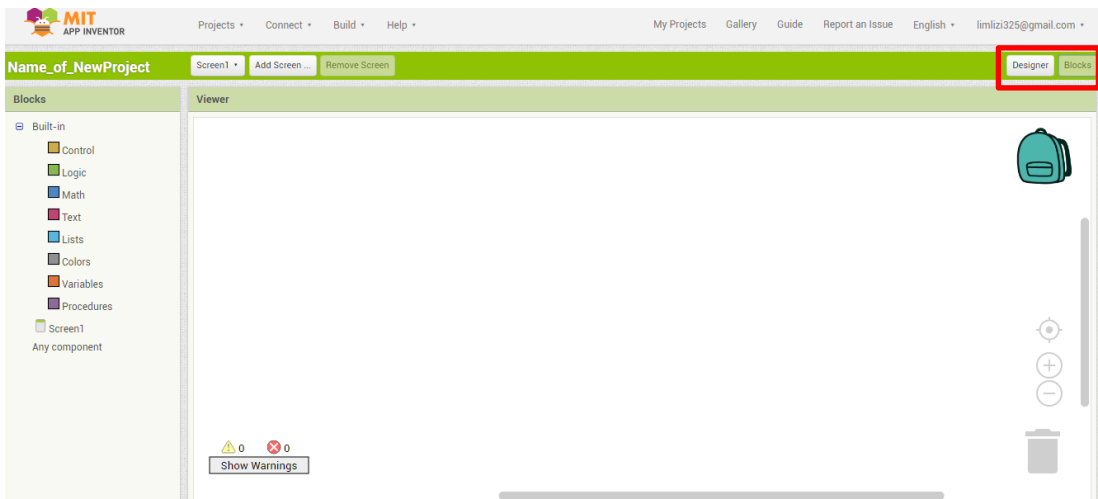

Figure 3.7: Overview of Designer

Figure 3.8: Overview of Blocks

3.5 Exploration of components

Various components were used during game development in this study. Used components were listed and functions were explained. In *Designer,* needed components were dragged and dropped to the screen.

3.5.1 User interface

1. Button (Button)

   Clicks were detected with button. Appearances of a button could be changed. The aspect (example: clickable) can be changed.

2. Check Box (CheckBox)

   Event was raised after the user clicked on it.

3. Image (Image)

   Images could be displayed with this component.

4. Label (Label)

   Text could be displayed.

5. Notifier (Notifier)

   Alert dialogues and messages could be displayed. Simple text is shown. Another option was available which was triggering event after the specific choice was selected.

6. Text Box (TextBox)

   This component displayed box for user to enter text.

7. Web Viewer (WebViewer)

   A web page could be viewed by inputting the URL using this component.

3.5.2 Layout

1. Horizontal Arrangement (HorizontalArrangement)

   Elements could be placed from left to right easily and neatly.

3.5.2 Media

1. Text to Speech (TextToSpeech)

   When text was inputted, voice was generated to speak the text.

2. Sound (Sound)

   This component played short sound file

3. Player (▶ Player)

This component was used for long sound files. Background music was played with this.

3.5.3 Drawing and Animation

1. Canvas (Canvas)

A two-dimensional touch-sensitive rectangular panel. Drawings could be done and sprites could be move within the region. Properties such as background colour, background image, width and height of a component could be adjusted.

2. Ball (Ball)

A round sprite which could be placed in canvas. Based on behaviour, it could react to drag and touch, interact to sprite (image sprite or other ball) and edge of the canvas. Only radius and colour of ball could be changed.

3. Image sprite (ImageSprite)

Function of image sprite was the same as ball. The difference was appearance of image sprite was gotten from an image file while the appearance of the ball was fixed.

3.5.4 Sensors

1. Clock (Clock)

This was a non-visible component which uses internal clock on Android device. In this study, it was used as a timer.

3.5.5 Storage

1. Fusion Table Control (FusiontablesControl)

Data can be stored in Fusion Table which was extracted from Google.

3.6 Exploration of blocks

There were many blocks to be used in *Blocks*. Blocks used were dragged and dropped to the screen. Function of the frequently used block was explained. A list of blocks were shown in Figure 3.9.
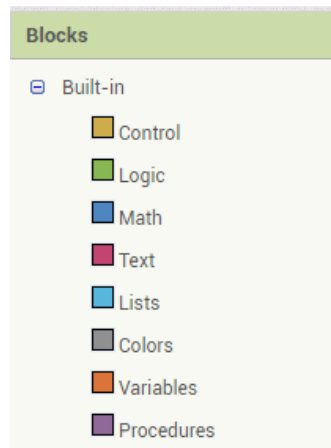
Figure 3.9: List of blocks

3.6.1 Control

1. If then ( )

   If the condition was true, event will be triggered. Else, blocks were ignored.

2. If then else ( )

   If the condition was true, an event will be triggered. Else, another specific event will be triggered.

3. Open another screen ( )

   Screen with mentioned name will be opened

4. Open another screen with start value ( )

   Screen with mentioned name will be opened and a value was passed to the next screen

5. Get start value ( )

   Value from previous screen was got

3.6.2 Logic

1. True ( )

   The condition was represented to be true.