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Master's Thesis

The implications of virtual prototyping in new product development: An experiment through gamification

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ABSTRACT

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To sustain in competitive business markets, company needs to take advantages of new technologies. Virtual prototyping is one of the technologies that can make the difference in the challenging markets. Consideration of users' needs and taking effective feedbacks from them are also crucial to face the challenges. This thesis examines the role of virtual prototyping and involvement of users in new product development in a new way. The aim of this study is to explore the incorporation of gamification with virtual prototyping in new product development for a particular product. The involvement of users in product development is one of the important and challenging issues for the company. The gamification event using the virtual model of particular product provides the effective solution of involving the users. The experimental part of this study was to arrange the gamification event using virtual prototype of particular product and obtained valuable information. Primary data have been collected from the interviews of participants in the gamification event as well as from the game data. This is a unique work in this field and the findings support the positive outcomes reached from the whole experimental processes and direct the possible means of getting the important information from experiment for the product development team as well as for the future researchers.

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1 INTRODUCTION

This master's thesis is based on experimental study in the field of Industrial Engineering and Management and the author of this paper will introduce briefly the background, objectives, and research questions with the overall structure of the paper in this chapter. In relationship with the research topic, the focal points for the author are the aspects of virtual prototyping and its relationship with the new product development as well as user involvement. This kind of experimental research is the result of author's deep interest about the topic. The work has been done under the department of Industrial Engineering and Management of LUT School of Business and Management.

1.1 Background

Quality product with low cost is always the demand for the consumers. The variation of products within shortest possible time to market has been the criteria to be succeeded in the market for the firms (Pine, 1993). Thus, virtual prototyping is helping firms to chase the challenge accordingly.

However, the versatile applications of virtual prototyping and simulation in company especially in product development depict the importance of using it and its potential aspects in future. According to the Shannon (1975), "Simulation is the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and evaluating various strategies for the operation of the system." Along with the simulation, the virtual prototyping and relative experimentation create the new types of competences and support to generate required outcomes in products and processes (D'Adderio, 2001).

Nowadays, industries are facing tremendous variations in business market especially in developed countries where the price of product and service are costly for the manufacturing industries to serve the markets. The economic recession has made the challenges tough, thus, business organizations need to be more versatile in the engineering tasks (Serdar, 2009; Horvath et al., 2010). The shorter product life cycles, rapid changes of customer demands, market competition and complicated logistic systems have intensified the challenges for the industries. Thus, company strives to introduce customized, better quality product to market earlier than other competitors (Ameri and Dutta, 2005). The importance of new product development is considered as cost making factor than adding the value to the organization. However, competitive markets, advancement of technology as well as the changes of product life cycle motivate the company to develop new product eventually (Unger and Eppinger, 2011). The success of company can be defined through the innovative and efficient product development process (Ameri and Dutta, 2005). Hence, the rapid change and complication in product development need the innovative solutions that assist different sectors to meet the challenges (Alves, 2007).

Over the time, new methods and technologies are coming to deal with the new challenges. These consist of factors such as the easy interaction between the real world and virtual world, computer simulation modeling, systematic management of product lifecycle (Horvath et al., 2010). Virtual reality is the basis of changing the design and prototype modeling by using the computer aided design systems and user interaction within its virtual environment (Amditis et al., 2008). Simulation can be a potential tool if it has been used appropriately with having good knowledge of it (Ingalls, 2008). Thus, in product development process, virtual prototyping with simulation has been extensively using. This has actual benefits of lessening the time of product development, reducing the physical product costs, more efficient and quality product with having easy management activities (Cecil and Kanchanapiboon, 2007).

1.2 Research Objectives and Research Problem

The questions behind the research need to be applicable and reasonable for the desired information both in business as well as in academic research. Therefore, there must have clear objectives for the study (Greener, 2008, p.10). The purpose of the research can be more than one and Robson (2002) stated that the purpose could be changed over time. The main objective of this research to test the hypothesis of using virtual prototype of particular product through the event of gamification aiming to be benefitted in product development by involving users. The following research questions have been formulated guiding the whole experimental study:

Research questions:

R.Q. 1: How to use virtual prototyping in new product development by involving users through the gamification?

R.Q. 2: What are the essential elements needed to have in gamification event using the virtual prototype model for the new product development?

In general, research gap shows the option of further study for a particular topic. The critical review of previous literatures can be helpful to figure out the shortfall and possible research work on particular study arena. It is very important to concentrate on the objectives of desired research to figure out the gaps comparing with other studies in related fields (Saunders et al., 2009, p.66). This research work is unique in a way that from the previous work, it has been seen that in new product development, the usage of virtual prototype of excavator through gamification is totally absent. Thus, author of this research has taken the opportunity of this research gap and has tried to figure out the possible outcomes though an experiment.

1.3 Theoretical Framework

The topics and concepts comprise the theoretical framework of this thesis are illustrated in figure 1, where the outcomes of gamification event using virtual prototyping are tested to the new product development process. The systematic ways used in this thesis have been demonstrated in the next section. However, the experimental tool of this thesis is gamification event. Use involvement is very important in new product development. Thus, for the effective use of potential users in new product development, gamification event has been arranged in a way to engage the users actively.

Virtual prototyping has been using in different researches and in engineering works to a significant extent. Virtual prototyping can be described as the virtual reality model based on the science and engineering field that can simulate the system's nature, structure and other characteristics with the high level of authenticity comparable to the real systems. The paybacks of using the virtual prototyping techniques consist of finding the manufacturing faults and design improvement with reducing the lead time as well as developing new products (Cecil and Kanchanapiboon, 2007).

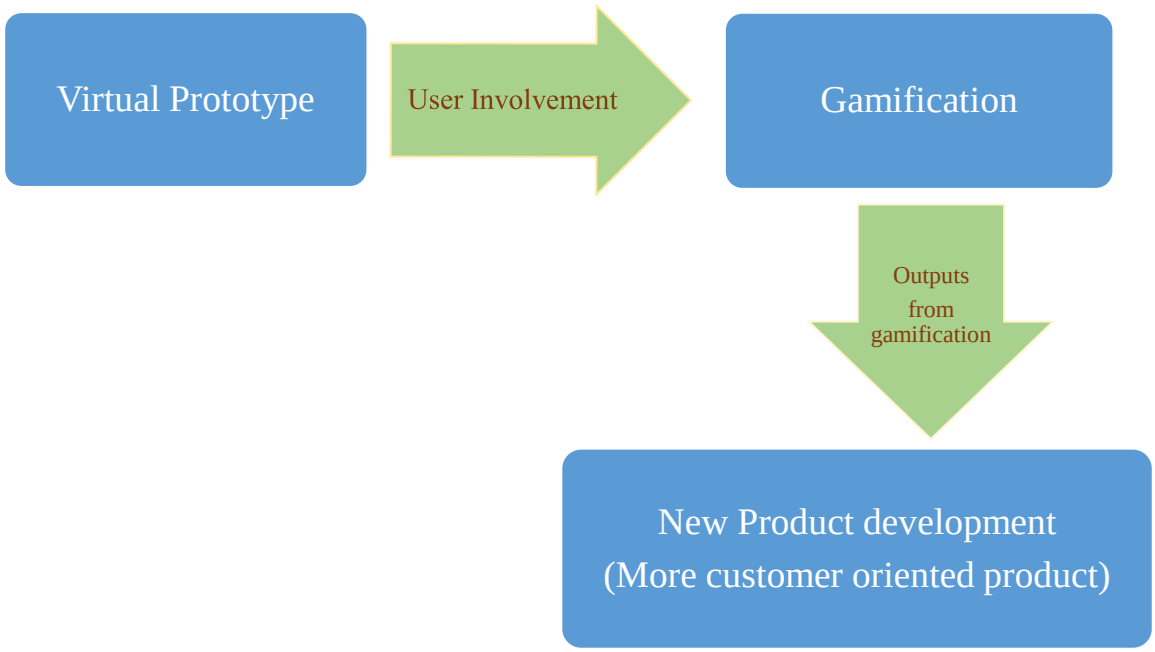

Figure 1: Theoretical framework

The above terms need to be discussed first for the clear understanding of the whole process of this study. Numerous literatures have been used to find the definitions and make the structure of the thesis more comprehensive. Systematic ways of searching key words have been used in this study and the results are mentioned in **Appendix 1**.

Although, gamification is the term for the non-game setting, the solution can be found from the event of gamification instead of just the lively contact of game elements. Gamification is a new development in the sector of business and marketing and it has currently been highlighted by the academicians, educational personnel as well as the companies in different fields (Nelson, 2002).

A successful product development needs not only the different tools and methods but also the right organization to support the development processes and the challenging issue here is that majority organizations are not directly involved with the design of the product rather work in more operational need (Tidd et al., 2011, p.382). The following figure 2 illustrates the process of new product development.

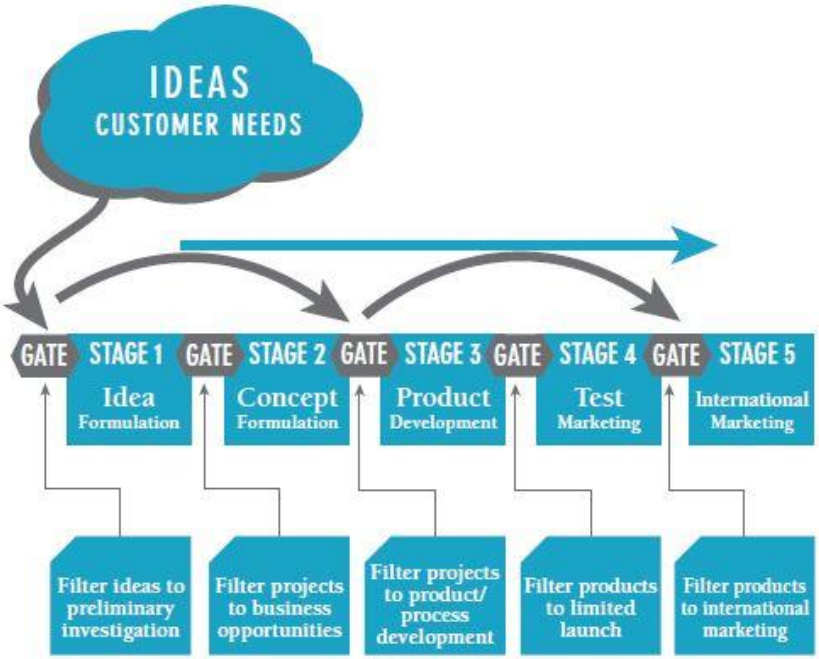

Figure 2: Process for new product development (Tidd et al., 2011, p.381)

In this study, experiment has been done on virtual prototype of existing product that can generate new product with different product features. The intense motivation for a company to develop a new product or work on existing product is to accelerate the business growth. The prospective rewards behind this are also huge (Trott, 2012, p. 420).

There is a Japanese proverb “okyakusama wa kamisama desu” which means Customer is God (Melin et al., 2007). Thus, satisfaction of customer is the main part to continue a business. To meet the requirements and expectations of customers, company needs to identify those needs with specific ways and then turn these needs to product design eventually. Traditionally, organizational perspective is to take those requirements from customers in a way to identify the features of product but this study deals with the more specific ways to get the most effective design criteria for particular product. The participants of the event of gamification in this study have been considered as potential customers for the particular product used in the study. Their feedbacks have been considered as important source of data for the product along with other game data.

1.4 Structure of the Thesis

The following table 1 illustrates the structure of the study. In the middle column of the table represents the main chapters of the study. The inputs of each chapter in the left column of the table have been used to get the desired outputs represented in the right column. The illustration helps the readers to understand the logical progress of the study. The desired outcomes of each section can be found in the output column.

Table 1: Thesis structure

Inputs	Chapters	Outputs
Background knowledge and study motives	1. Introduction	Research objectives, gap and questions
Secondary data	2. Literature Review	Providing ideas about key issues of research through reviewing previous literatures: • New product development • Virtual prototyping • Gamification • User's roles and potentiality in product development
Background works for the experiment, primary data collection	3. Methodology	Used methods and accomplishment of experiment
Primary data	4. Data Analysis and Results	Answering the research questions
Whole study summary	5. Discussion and Conclusion	Assessment on reaching the objectives of the study and summarizing the results

2 LITERATURE REVIEW

In the introduction section, the common challenges of product development have been mentioned briefly and in this section, the challenging factors of new product development have been summarized as well as the previous literatures regarding the usage of virtual prototyping in new product development have been piled up.

The main challenging factors for companies to think about the innovative product development process can be summarized based on the aim of this paper:

- The context of expansion to global market, shorter product lifecycles, demand of customized products (Ovtcharova, 2010; Ameri and Dutta, 2005)
- Need quicker, efficient and cost effective product development (Durmusoglu, 2009)
- The manufacturing and product design process require more communication networking amongst the team (Ameri and Dutta, 2005)
- The less usage of technology in product development and innovation process (Koudal and Coleman, 2005)
- The need of using less time and cost reduction in new product development push the companies to use new technologies and tools in development processes (Mujber et al., 2004).

The above challenges can be met though the applications of virtual prototyping and simulation in the product development process which is an ideal solution to skip the physical prototyping eventually (Mujber et al., 2004).

2.1 New Product Development

To figure out the customer needs and opportunities of market and the early identification of product requirements are essential (Sinclair and Campbell, 2014). The new product development deals with the management rules and regulations in the phases of developing the products. The disciplines are related to their own standpoints on the topics of new product development. Thus, there is no general tactic for the development of new product because of the different perspectives (Trott, 2012, p. 418). In this paper, the main concerning part is limited to the design and engineering. The perspectives are shown through below figure 3.

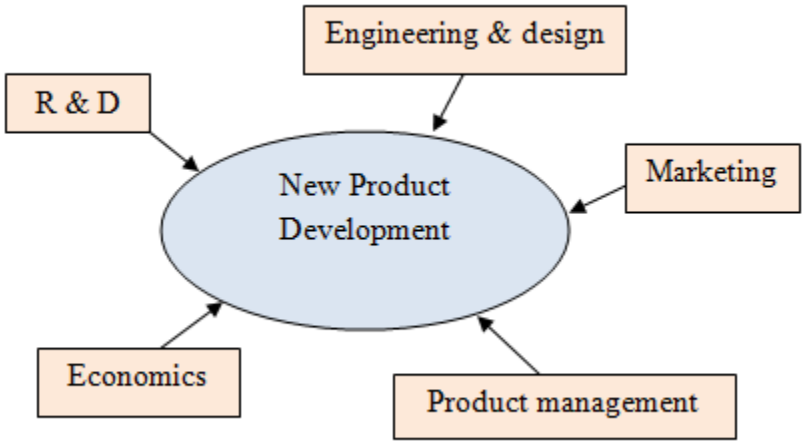

Figure 3: Perspectives to study the new product development (Adapted from Trott, 2012, p.419).

- **Categories of new products**

The classification of new products has been done in many ways, whether the comprehensive categorized has been done as below (Booz et al., 1982; Trott, 2012, p. 429):

1. New to the world products:

   This kind of product is very new by its type and in market. The innovative features of this type of product sometimes starts a new way for revolutionary effects to market such as touch screen IBM Simon introduced in 1992 (O´Malley, 1994).

2. New product lines:

   This is not very new product but new for the particular organization. The company tries to grab a major portion of market through this type of product. This is true in mobile market where many new mobile companies are trying to capture the market by their own products.

3. Additional lines:

   This type is just an additional line with existing one and the product is similar to the current one with adding some additional features. For example, in addition to the baby wipe/dry diaper, Pamper introduced splashers swim diaper for the baby swimmers (Pamper, 2017).

4. Upgrading and modifications of existing product:

   This is the product replaced to the existing product as it has been modified in some extend with more efficient and reliable than existing one such as Toshiba´s first laptop PC of 1985 gradually has been modified time to time now becomes modern laptop.

The experiment has been done on virtual prototype of existing product where the improvement and modification can be possible to generate new product with improved features.

2.2 Trends of New Product Development

Product development processes are the techniques and approaches that organization works on to plan and design new products for the market, and effective product development process is essential to decrease the development time, having quality product and reducing the risks (Unger and Eppinger, 2011). To get the competitive advantages, it is necessary to study product development process and numerous researches have been done on this field (Ibusuki& Kaminski, 2007). Therefore, it is important to maintain or improve the development process with suitable tools from the very initial of designing the product concept to the production of the product.

The difficulties within new product development create two issues, firstly, effectiveness of development process meaning doing the right things which comprises basically the questions to figure out the actual customer needs and secondly, the issue of efficiency meaning doing things right. This includes different problems such as absence of standardization of process, communication gap, less control over the mass production activities with derailed from main goal (Hines et al., 2010). There are some other issues related to the failure in product development process such as inability to get the learning outcomes, poor evaluation methods, hindrances in communication (Ameri and Dutta, 2005).

Hence, the goals of company include the decrease of developing time, cost as well as the smooth entry to market. Therefore, improving the product innovation with high quality features and flexibility are needed for competing in global market. The problem can be solved through concentrating in key process such as design process where virtual reality can be applied for creating virtual prototype of product (Zachmann, 1998).

The process of new product starts from the original concept with going through some decisional processes and activities to design and commercialize the product. The idea of particular design needs to assess with some repetitive development processes form the initial and simulation of the system is important to back the iterative design process (Maguire, 2001).

2.3 Customer Roles in Product Development

The participation of customer is projected to improve the quality of system. However, by involving the users in the process, it can provide accurate and useful list of customer requirements with the know-how of organization to eliminate the unnecessary attributes and can improve the user's understanding (Ives and Olson, 1984). However, the difficulties are also involved to get the information from potential users for the new product proposition. There are several steps and components for developing the new product and thus changing one parameter can have effect to other important features of product. In this circumstance, user can select one new criterion of product and then add the feature to the product to evaluate the utility of product. User can also find out the comparative benefits of new product with new feature with existing options (Lilien et al., 2002).

Manufacturer can face problem to transform the important but sticky requirements to new product. The need related information sometimes becomes very expensive to implement to the new product for the developers. Thus, overcoming the difficulties, the user requirements can be changed accordingly to the new product. There might have several discussions between the customer and developer to reach the satisfactory product concept (Sanden, 2007).

The role of customer can be segregated through three different ways, which are customer as resource, customer as co-creator and customer as user. The phases of new product development for corresponding roles are as ideation, design and development, and product testing with support respectively. The key issues regarding the role of customer as resource are customer is a source of innovation, customer incentives, the support and infrastructure of acquiring customer knowledge and the gap of defining the role of existing and future customers. On the other hand, the participation in different design and development tasks, the types of products, coordination in product development team and improving the product knowledge of customer are the main challenging issues for the management when customer acts as a co-creator. As a user, the key factors are more likely the time constrain activity, support customer diversity and ensuring the effective customer-to-customer interaction (Nambisan, 2002).

Organizations can be indifferent to ask and collect the information of new product from the customers due to the incomplete information and customers generally think too much about the product attributes. However, customer might fail to predict the future value of product. It can be fruitful for company to collect information directly from customer rather can concentrate on own research team (Flint, 2002).

However, the important roles of customer in new product development are needed to be acknowledged and in this paper, the customer involvement in product development has been tried to explore by the experimental design.

2.4 Virtual Prototyping in New Product Development

From the previous literatures, it has been seen that in engineering design and development, virtual prototyping has been being used effectively. The interpretation of the term by the people in various ways makes it a little muddle. The following definitions should make it easy to understand:

Virtual prototyping is quite new tool, which is connected with virtual reality more likely using it and with different computer technologies (Gowda et al., 1999).

On the other hand, Song et al. (1999) denotes the virtual prototyping in perspective of product design and development. The processes of simulating the product, customer needs and the collaboration between these continue in different phases of product design, analyze and development.

Virtual prototyping with virtual reality practices deal with real facts that can emerge the possibility of experiencing virtual worlds. The improvement of presentation quality is the outcome of virtual reality when it is added with electronic prototyping. This method of object manipulation creates new prospects for prototyping CAD (computer-aided design) based models. To test and analyze the functionality, geometry and manufacturability of a particular the product, the data model of that product can be collected as virtual prototyping as an alternative of taking the real product (Astheimer and Gobel, 1995).

Additionally, the Virtual reality makes it enable to understand the virtual worlds easily. The new prospects for prototyping through the CAD models are the outcomes from the application of VR. It is now possible to use virtual models instead of real models and then analyze the prospects and consider the design issues of products respectively (Astheimer and Gobel, 1995).

In new product development, virtual prototyping becomes the important tool for the designers, engineers, product developer to collaborate with each other for getting the solution in design and production phase. It enables the producers as well as customers to identify the issues related to the usability and fix it prior to production, which can eventually save time and money for the organizations. The development process of product can be accelerated through the VP (virtual prototyping) and it changes the idea of product planning and design by its potential applications (Peter, 2001). The following figure 4 illustrates the basic of virtual prototyping in automated industrial systems:

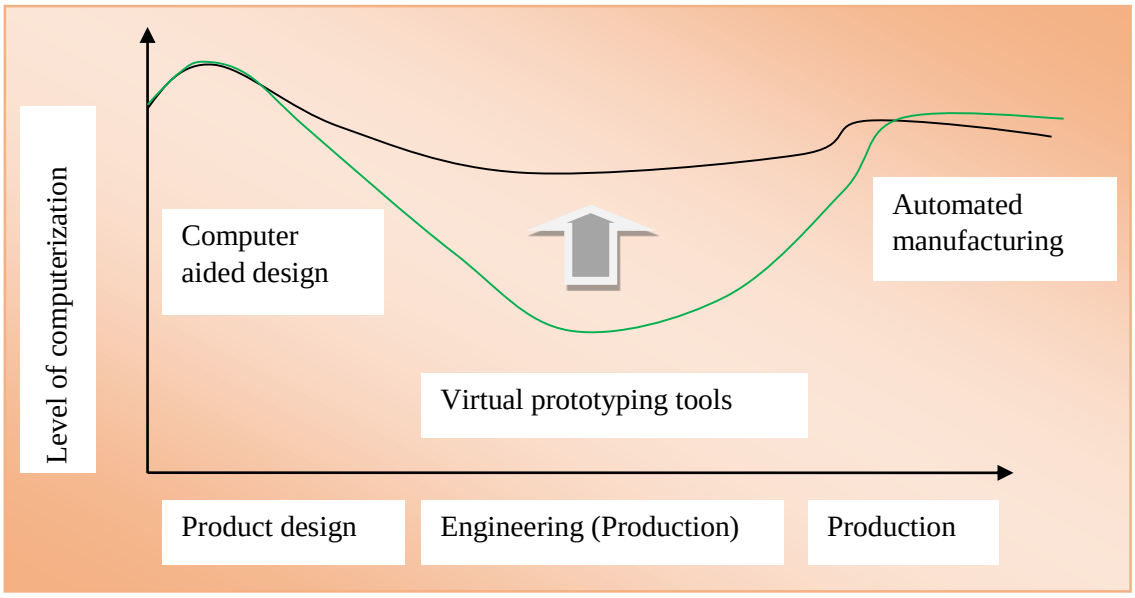

Figure 4: VP in automated industrial process (Adapted from Ledere, 1995).

According to Ovtcharova (2010), the new approaches and methodologies are the results coming from the demand of a particular time. Rapid growth of global market demand and technological advancement make the business criteria more competitive and requires the suitable tools for

product development. He proposed a transition process curve for the digital engineering by following figure 5:

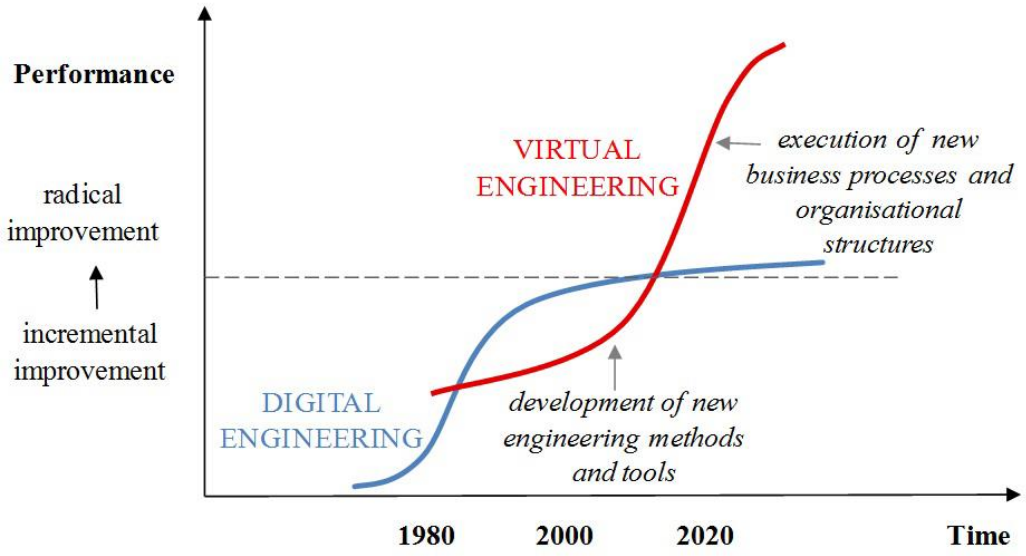

Figure 5: Curve of transition process (Ovtcharova, 2010, p.1268)

2.4.1 The Benefits of Virtual Prototyping

Virtual prototyping has been considered as a radical tool for a long time in the new product development as well as manufacturing process development (Schmitz, 1998). It has been seen that the industrial organizations get the benefits of virtual prototyping in their product development processes followed by those who actually got the advantages by earlier adoption. Thus, the advantages and potentials of VP need to be clearly understandable by the organization in advance.

The usage of virtual prototyping has been increased because it accelerates the process of product development and involves the stakeholders in the process. The main benefits of virtual prototyping consist of reduction of making physical prototype, efficient communication amongst the development team, the initial concentration to downstream issues and minimizing the expenditure of product development. Additionally, the changing of design in the initial

phases of product life cycle becomes easier for the team (Cecil and Kanchanapiboon, 2007). Better communication and concurrent engineering in developing team are also the advantages of virtual reality approach (Ovtcharova, 2010). Through the virtual prototyping, users' opinions regarding the product can have substantial impact to improve the design of the product (Pang et al., 2006).

Virtual prototyping can be used from the product design to the whole product life cycle. Users are the part in the process and the actual drivers of implementing virtual environment in the system. The benefits of using virtual reality and virtual prototyping have been seen in many industries (Amditis et al., 2008).

The benefits of virtual prototyping tools can be summarized through the below lists (Norton, 2001; Knowledge and McLeod, 2001):

- Early launch to market.
- Pre-testing of product.
- Costly or difficult tests can be done easily.
- No need for physical prototype.
- Increasing worker safety and ensure flexibility.
- No restriction for geographic issues.
- Offering standardization in design and language.
- Cost effective as high profit is possible.
- Accelerating the agility of organization.
- Decreasing the time and cost of development.
- Complex design can be possible.
- Easier to communicate and increase effectiveness amongst those who are involved in the product-development process.

2.5 The Scopes of Using Virtual Prototyping in New Product Development

The virtual prototyping method in new product development has been using by different manufacturing companies with small initiatives and they are getting the benefits accordingly. The applications of VP are mostly used in technical fields and researches but applications in the business arena are limited (Leino and Riitahuhta, 2013). A thorough evaluation of virtual prototyping in the perspective of having intended advantages and usability is absence in past works (Toma et al., 2012). Toma et al. (2012) ran an experimental research where they were trying to relate the interface of 2D user with 3D user structure. The virtual reality was included to get the perceive value from the system in an assembly process. Ironically, the benefits of 3D models over the 2D did not appear substantially and they concluded that the changing of consumer perception over the VP does work when using the virtual reality technology with it. Moreover, there are few studies done in the virtual objects and the advantages are anecdotal in nature (Gruchalla, 2004).

Cobb et al. (1995) showed the prospective of virtual environment and reality in manufacturing firm whether they urged to work on this topic further to find out the real benefits from it. However, Gomes de Sá and Zachmann (1999) predicted through a survey that the role of virtual reality in virtual prototyping would be a vital part in product development process soon. There is still lack of experimental data for the benefits of VP in different projects (Söderman, 2005). The obstacles of using the virtual objects are less visibility and recognition of the perceive benefits. It also intensifies due to the tough implementation of systems and technology (Amditis et al., 2008). Once, the method of using virtual prototyping was thought to be a costly issue and difficult to implement, however, it can be successful if the integration of knowledge, processes and support systems can be ensured. The virtual environment will be worthwhile practically in everything (Ellis, 1994).

2.6 Users' Involvement in New Product Development

It is not possible for the designers to know about the different users and their experience to use the intended products. There are many types of artifacts, which fulfill the requirements not only as the functional but also ambitious, spiritual, and emotional (McDonagh-Philp and Lebbon, 2000; Bruseberg and McDonagh-Philp, 2001). Kaulio (1998) proposed a framework of customer involvement in new product development. There are two dimensions such as longitudinal dimension and lateral dimension. The longitudinal dimension consists of involving the customer in the specification, concept development and prototyping phases. This dimension basically involves the customer in design phase although the involvement is limited. On the other hand, lateral dimension has been grouped into three different categories. The 'design for' is the first group where customer requirements are considered for product design. The second group is 'design with' consists of the revision of customer requirements and maintaining the formal interaction with customers. The third group is 'design by' which denotes the active involvement of customer in design and find out the important issues related to the usage of product. Thus, users are the important source of information to help designers to figure out the requirements of the products and necessary to be successful in business.

2.7 Users' Potentiality in New Product Development

The essential part of this paper is to figure out the ways to get user's requirements for product development and meeting the needs of customer effectively. It is hard for designer to be effective visionaries if designer doesn´t have the comprehensive knowledge how the upcoming product will be performed and the user preference over the product variations. Understanding the user requirements offers dynamic information for the designers (Bruseberg and McDonagh-Philp, 2001).

Users can propose important design criteria to assist the designing process. However, there is possibility of certain risk for the involvement of users as well. Sometimes users are not sure about their actual needs, thus, it cannot provide the right information. Coates (1997) stated the distinguishing factors between the normal product and the imaginary product. Normally the new

product is relatively close to the predetermined idea, although the difference between the stereotype product and imaginary product should not be too far. He evaluates the use of focus groups in research in marketing work. There should be the combination of both idea and physical product. Stereotype is the thing what users are aware of but on the other hand, the idea is sometimes vague to understand clearly by the users.

2.8 Gamification

In business arena, gamification has become a buzzword and the focus point is to evaluate the customer roles in it (Hymers, 2016). According to Deterding et al. (2011), "Gamification is the use of game design elements in non-game contexts". The practical implication of game design and the outcomes from the gamification practices are yet to explore properly in business world (Carignan et al., 2013). The idea of gamification has been using in business and by the product designer more frequently than before. The strong interest for the game by the society has changed the traditional thinking of product development and consumer market (Zichermann et al., 2011). Huotari and Hamari (2012), also define the gamification in perspective of marketing where the value creation is the output of gamification.

2.8.1 Applications of Gamification

Although gamification has the marketing applications, it has been using in different areas. The fields of designing and studying game are not the mainstream application of gamification but it is more than that (Sabourin and Lester, 2014).

Moreover, the technology and elements of game such as the three-dimensional game engine may be more suitable in non-game setting and it has many applications for developing the simulation tools in different fields. Normally, game engines include the realistic graphics features with sophisticated three-dimensional animation that make the environment more interesting. Additionally, Artificial Intelligence (AI) can be used in game design and these kinds of features are important to build desired environment (Wieman and Perkins, 2006; Bijl and Boer, 2011).

2.8.2 Elements of Game

The acknowledgment of game elements is very important to understand the gamification. Huotari and Hamari (2012) described the gamification in terms of the mechanisms of interaction and responses, which add values eventually. However, he did not clearly elaborate the processes of mechanisms. There are many methods for great games; however, successful game should have ten ingredients (Reeves and Read, 2009). Deterding et al. (2011) criticized the idea of ten ingredients. Rather he introduced different levels of generalizations of game design. The limitation of this framework is that the generalization is not effective for the context of different types of game design. The game design elements have been acknowledged with different levels of generalizations. These levels are described with examples by the following table 2:

Table 2: "Levels of Game Design Elements". (Deterding et al., 2011)

Level	**Description**	**Example**
The interface and design patterns of game	The fruitful interaction of game components and game solutions for the identified problem based on specific issue.	Leader-board, Level, Badge
Mechanics and patterns of game design	The recurrence parts of game design that deal with the game play.	Resource and time constraint.
The principles and heuristics of game design	The assessment and dictation of design problem and examine the solution of design.	Different game styles, specific aims and constancy in play.
Models of game	Theoretical model for the game experience and elements.	Mechanics-Dynamics-Aesthetics; challenge, inquisitiveness.
Game design methods	The processes and patterns of designing specific game.	Play testing, play centric design with value consciousness.

This level model can make a distinction between the interface patterns of design and game design or methodology. The application of particular game uses various elements related to the design of games (Deterding et al., 2011). The leader boards and badges, points are the most compromising elements of game (Huotari and Hamari, 2012).

2.8.3 Benefits of Gamification Adding with Virtual Prototype

The important advantage of using gamification is to increase the engagement and involvement of users. This kind of engagement helps to create communities to improve the collaboration. The strategic part is to train up participants with simulations and find practical feedback through group collaboration and group discussion with increasing competitiveness and aim to do better by the users (Brigham, 2015). Gamification creates challenges and new insights in regular life with using the instincts of human to get involved in competition to learn, improve strength, overcome the barriers and eventually win. The digital interaction by gamification makes the business environment more interactive and social (Deloitt, 2013, p.52). Developers are provided with important information about the types of the users, which are necessary to define the business objectives. Thus, the requirements of customer can be fulfilled appropriately. User-centric design of gamification can be increased customer satisfaction and productivity with minimizing errors to meet the business goals (Rajanen and Rajanen, 2017).

However, the benefit of gamification with using virtual prototyping seems to provide the same results as discussed above. This study is established to test the benefits incorporating gamification with virtual prototyping model by showing different types of comparison amongst the participants. The comparison of performance between the top performers and low performers in game has been considered an important aspect of introducing the gamification event. This kind of comparison is valuable because it makes the evaluation of current product features easier compared to traditional thinking of introducing new features or modification of current product features. Apart from this, valuable insights about the product and game itself can be acquired from the interviews of players. The details results regarding these outcomes will be demonstrated in the section of data analysis and results.

3 METHODOLOGY

In previous sections, the importance of using virtual prototyping in product development with some theoretical backgrounds of this experiment has been explained. This section has been designed to explain the processes used for the study as well as discussing the process of experimental in details. The approaches and types of study have been mentioned here. Furthermore, the systematic process of experimental design has been described.

3.1 Research Design

According to Collis and Hussey (2013), research can be classified based on the purpose, process, outcome and logic. The purpose of the research can be exploratory, analytical or descriptive. The methodology could be the quantitative or qualitative as well as the approach could be inductive or deductive.

The purpose of this thesis is exploratory study that deals with the new things, areas need to be explored and generate concepts and hypothesis for further work (Robson, 2002).

The approach of this study is more likely deductive where researchers generate hypothesis from theory and then check the data to accept or deny the theory (Creswel et al., 2007). The figure 6 represents the process of deductive approach.

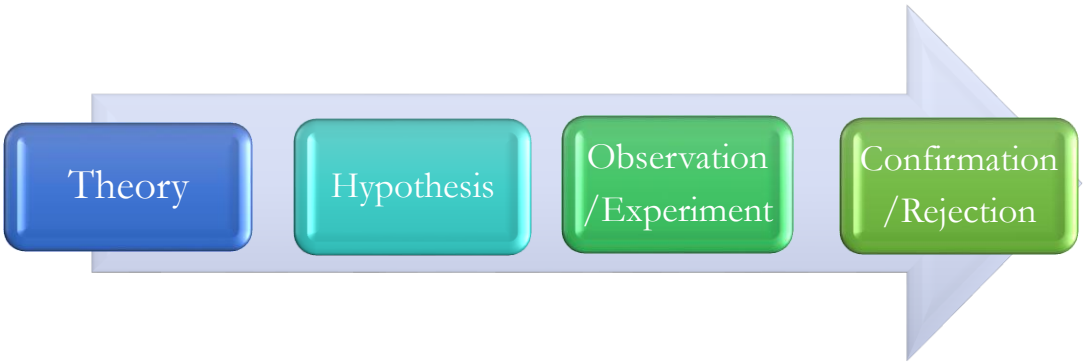

Figure 6: Deductive approach of research (Adapted from: Saunders et al., 2009, p.124)

The semi-structured interview is one of the data collection methods in this research, which is in the midst of structured and unstructured interviews in nature with having preliminary set of questions (Saunders et al., 2009, p.320). Moreover, both qualitative and quantitative methods have been used in this study.

This thesis is about the experimental study, which is "The best method— indeed, the only fully compelling method—of establishing causation is to conduct a carefully designed experiment in which the effects of possible lurking variables are controlled" (Moore et al., 2009). To find out the potential cause and effect between different variables and test the idea, experiment can be a better choice (John, 2012).

3.2 Design of Experiment

The usage of virtual prototype of excavator has been tested through the gamification. The whole experimental process had been done through two stages of gamification. The stages are named as gamification phase 1 and gamification phase 2. The game criteria of these two phases were little different in terms of tasks and platforms and participants. In this section, these two phases will be described accordingly.

3.2.1 Gamification, Phase 1

The main task of arranging the gamification event had been started once the virtual model of excavator became ready to use. The model has been made by the Mevea software. There are several reasons of using Mevea software in this research such as:

- One of the market leaders in real-time simulation and in simulator providers.
- Providing simulation solution with advance human-machine-environment interaction
- The user friendly interface with real control system
- The easy modification is possible for different parts of machine as well as environment.
- Expert opinion was available when designing the game interface for this experiment.

This kind of real time simulation of virtually prototype excavator which has been used in this study comprises the mechanics of machinery, actuators and the interaction between the device and surroundings. This includes also the external structures connected with I/O interface (Mevea, 2017). The virtual model is common crawler type excavator as the figure 7:

Figure 7: Virtually modeled excavator for the experiment

The platform was desktop computer with joysticks appropriate for using the modeled excavator for the first phase of gamification event such as the following figure 8:

Figure 8: Platform used for the first phase of gamification

After fixing the date of event, players were invited for the event. The players were basically from university students as well as university staffs for this first phase of game. Moreover, to avoid any biasness, players were chosen randomly from four different nationalities. 84% of players did not have any previous experience of participating game using virtual model and nobody had any experience of using real excavator. The rest 16% had the previous experience of using virtual model although it was not the similar type of model used in this study. The reason for choosing new users was to find out the intuitive of the virtually modeled product and the below figure 9 shows the percentage of experience players in terms of using simulator:

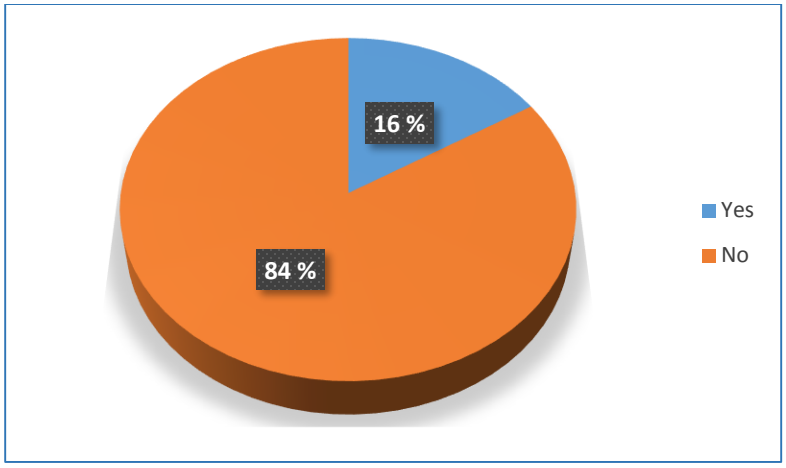

Figure 9: Previous experience of using simulator

However, before starting the game, objectives of the game and instruction of using the tools were mentioned and provided in a written form as well. The task was to load certain amount of material and put it in industrial hopper. Players had freedom to take the material from any place of ground. Movement of whole excavator was not needed. All players had the chance of using the virtual model as a trial before starting the actual game. After finishing the 1st attempt of playing the game by the all players, players had to sit for the second attempt. Time showed after the completion of task on the screen. Leader-board was created based on the averaging times of their two attempts for accomplishing the given task. Players were interviewed later.

The following figure 10 depicts the systematical activity flowchart of process:

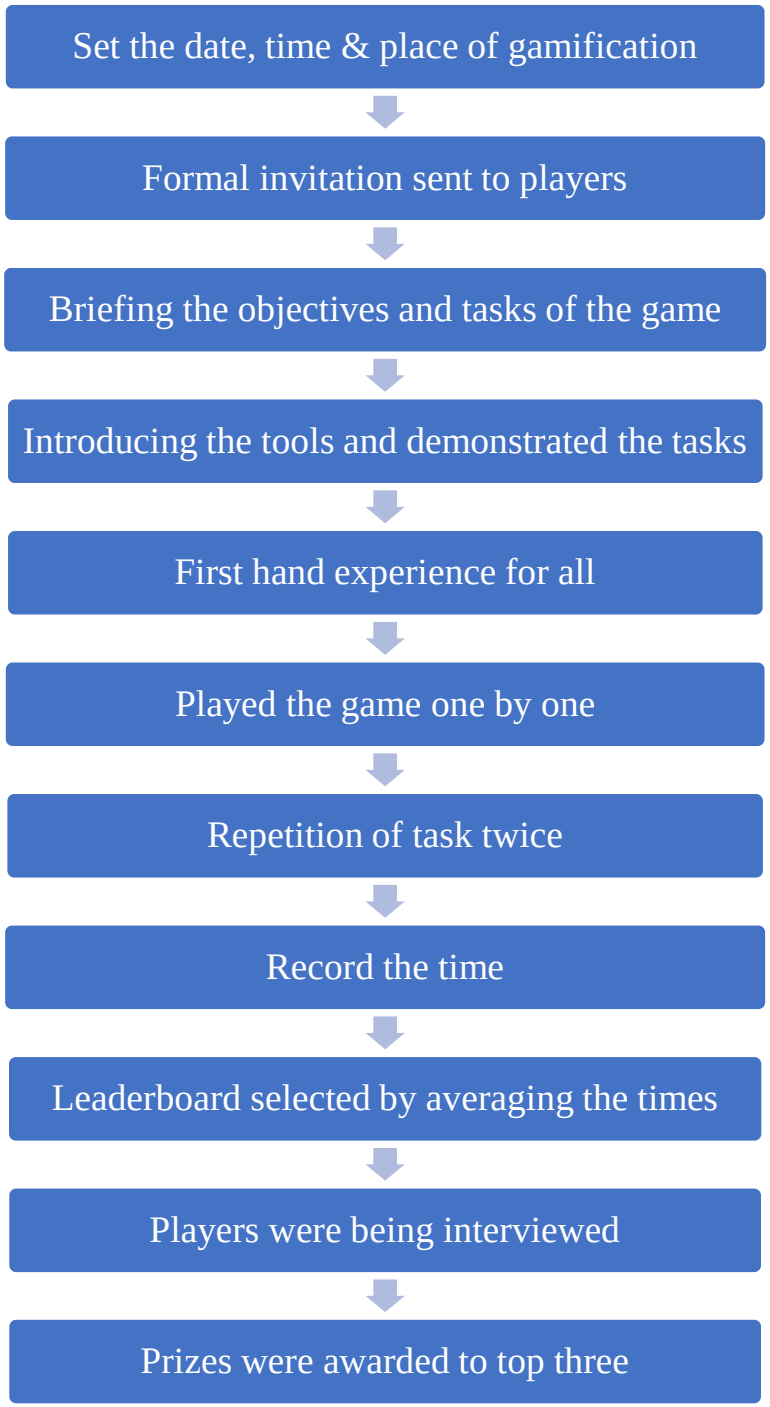

Figure 10: Activity flowchart of gamification, phase 1

Time was the only parameter to make the leader-board. The full name of the players has been omitted due to privacy issue. The below table 3 represents the result of first phase of gamification:

Table 3: Leader-board of gamification, phase 1

Players	Time (1st)	Time (2nd)	Average Time	Position
Niko	1,14	1,40	1.27	Winner
Alisa	1,29	1,42	1.36	1st runner up
Fakhrul	2,27	1,1	1.69	2nd runner up
Yan	3,19	1,36	2.28	4th
Zheng	3,40	2,44	2.92	5th
Sajib	n/a	3,14	3.14	6th

Each participant of the game has been interviewed in quest of seeking the answer of research questions. Face to face interviewed were done for this phase of gamification. Audio recording was used for the interviews and later transformed into the written form.

3.2.2 Gamification, Phase 2

The same model of crawler type excavator was used for the second phase of gamification. However, this time the platform was the SIM Studio. The SIM Studio is the replica of real excavator and user can feel the same vibration, tilting, sound in this platform. The control system is more or less the same as the real one. This platform is situated in corridor of LUT (Lappeenranta University of Technology) campus and open for all to experience the virtual simulation of equipment like excavator and tractor. The figure 11 shows the mentioned platform:

Figure 11: SIM platform

The invited players for the second phase of game can be segregated into three types such as very new users, some players who were also the participants of first phase of gamification and some people from company who have the experience of using real excavator. Moreover, the players were from university students, staffs and professional personnel from company. Again, to avoid any biasness, players were chosen from different nationalities. Players were from six different nationalities chosen randomly. The figure 12 illustrates the experience level of players in terms of using simulator and real excavator:

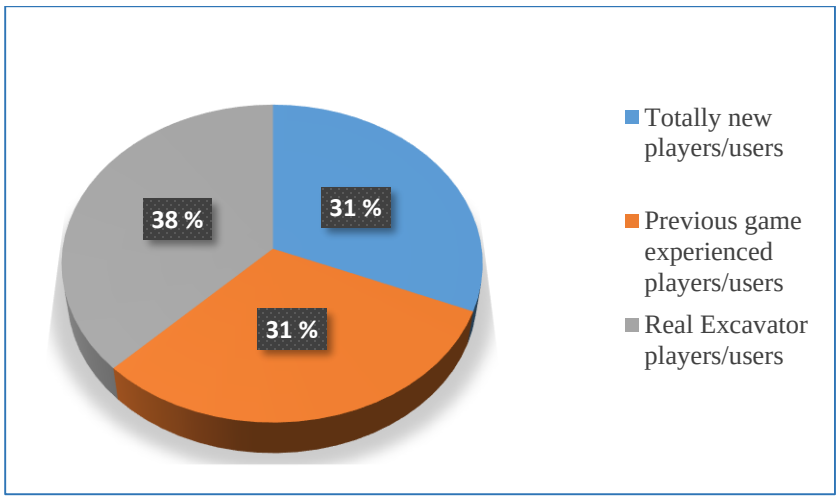

Figure 12: Players' experience in the second phase of gamification

However, on the event day, before starting the game, players were instructed about the objectives and tasks of the game. This time, players could choose different types of buckets and hydraulic cylinders and the comparative advantages of each type were briefed before starting the game. The figure 13 shows the used buckets and hydraulic cylinders in the second phase of gamification:

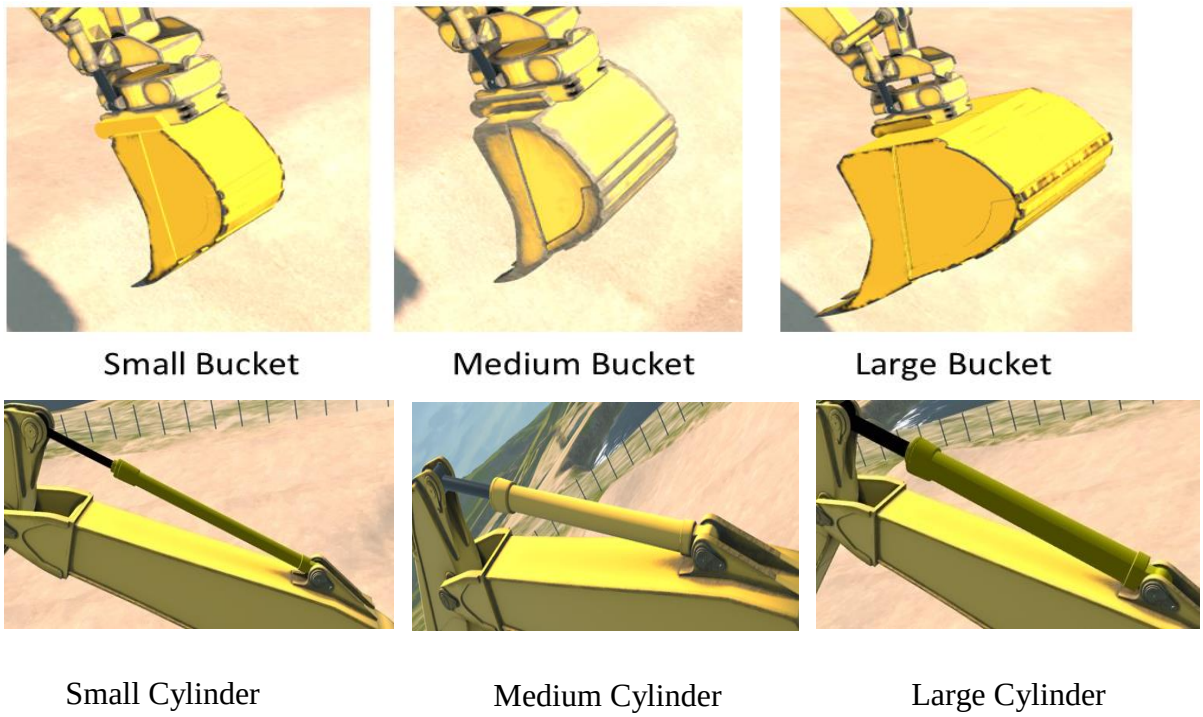

Figure 13: Different types of buckets and hydraulic cylinders

The task was to load certain amount of materials from any place of ground to unload to the industrial hopper. However, this time, additional obstacle was created and put it near the industrial hopper and players needed to avoid hitting the obstacle as the maximum chance of hitting the obstacle was 3 times. Thus, if number of hit was more than 3 times, game was over automatically. The indication of how many times player hit the obstacle was put on screen. Another criterion was fuel. Players needed to think about the fuel consumption that made the task more challenging. The fuel meter showed the fuel consumption on screen. After completion of task, the time showed on screen and players had to play three times. The leader-board was

generated by the average calculation of three attempts considering the three criteria. The activity flow chart of the second phase depicts as below figure 14:

Figure 14: Activity flowchart of gamification, phase 2

The following table 4 demonstrates the leader-board of second phase of gamification:

Table 4: Leader-board of gamification, phase 2

Players name	Average fuel used(L)	Average Time to finish task(Sec)	No. of Hit	Avg. Weighted score with proportion	Leader-board
Sajib	0.825	66.133		49.784	Winner
Niko	0.858	67.374	1	52.851	1st runner up
Kari	0.932	69.801		55.651	2nd runner up
Mikko	0.952	76.148		61.401	4th
Simo	0.997	78.664		63.475	5th
Sayed	1.045	91.904		62.986	6th
Janne	1.068	84.808	1	63.680	7th
Aleks	1.114	78.864		62.049	8th
Benkeltoum	1.189	127.551	1	99.854	9th
Zheng	1.207	131.016		93.483	10th
Mustafa	1.216	125.224		96.935	11th
Farhad	1.316	136.229		103.450	12th
Daniel	1.391	132.570		90.245	13th
Mahmoud	1.470	134.165	3	88.455	14th
Kimmo	1.672	131.926		112.024	15th
Yan	n/a	220.343	1	n/a	16th

It has been said that there were three criteria to find out the winner as well as the rest in leader-board. However, the weighted value of every criterion was different. The below table 5 shows the percentage of weighted value:

Table 5: Criteria of game with weighted value

Criteria	Weighted value
Time	+70%
Fuel	+30%
Hitting obstacle	-10%

Moreover, another important factor was to consider the experience of players to calculate the score of each player. Additional 10% value had been added with the final score of real excavator users and 5% additional value had been to the score of those players who participated in first phase of gamification. The total calculation sheet can be found in **Appendix 3.**

Players have been interviewed to find out more specific answers of research questions. For the second phase, face-to-face interview has been done. The outcomes of the interviews have been explored through answering the research questions in the section of data analysis and results. Some answers of interview questionnaires can be found in **Appendix 2**.

3.3 Methods of Data Collection

Interview is one of the best methods of collecting data for the qualitative research. Conversation is the main pillar of qualitative interview. There are different types of interview methods such as narrative interview, factual interview, focus group interview, confrontational interview (Kvale, 2008). The researcher has to distinguish and choose the suitable methods for dealing with the requirements of the research question. After that, the researcher needs to make decision and select the appropriate methods of study. There are complexities to collect data in spite of the need of it obvious. Interview is one of the finest methods of data collections (O'leary, 2004,

p.162). Interview has been using to collect data for a long time in qualitative research and has become an important instrument of research due to following reasons (Gray, 2014, p.214):

- Highly adapted data can be achieved.
- The opportunities are needed to astute.
- Effective return rate is possible.
- Geographical limitation can be overcome.

Interview can be categorized into three different types. Structured interviews consist of questionnaires, which are predetermined and standard form of questions. In the semi-structured interviews, researcher should have a list of themes and questions to be answered. The order of questions can be differed due to the types and course of conversation (Saunders et al., 2009, p.320). Unstructured or in-depth interviews is informal interview and there is no predetermined questionnaire thus, researcher should have the clear idea about the goal of the interview (Saunders et al., 2009, p.321).

Semi-structured interviews have been used in this study. It has already mentioned that the type of interview was face-to-face. The contents of the interview were formulated in a way to find out the intended outcomes meeting research objectives. The questions were slide different for the experience users from the company and the new users as some questions were not suitable for all the interviewees. For the first phase of gamification, interviews were taken by audio recording with the pre-determined questionnaires and tried to get more details rather than just get the answers of specific questions. The time and date for the interviews were set such a way to make the participants comfortable getting best outcomes from those. The questionnaires for the second phase of gamification were in two languages such as English and Finnish. The reason behind the conversion of questionnaires to Finnish was to obtain the exact answers of questions from the native Finnish speakers participated from the company. Some of the interviews were accomplished immediately after the game and others were in different times and dates.

Another data source for the study was the game data. For the first phase of gamification, the parameter was only time and it was easy to record and calculate. However, for the second phase of gamification, there were different types of parameters. Data like accomplishing time of the task, fuel consumption, number of hit, arm movement were recorded automatically and stored for later usage. The format of data was in .xml file and author converted the data from .xml to .xlsx format due the easy calculation. Each player played three times, thus, there were 48 data set for the 16 people needed to calculate.

4 DATA ANALYSIS AND RESULTS

In this chapter, the results of gamification event have been described. The event has been done based on the virtually modeled excavator where the real time features are included. In this section, the data collected from the interviews and the gamification event have been analyzed. The whole process of analyzing data and finding the results have been done through answering the research questions.

R.Q. 1: How to use virtual prototyping in new product development by involving users through the gamification?

The event of gamification using the virtual prototyping for a particular product can be a specific solution for the company to figure out the issues regarding the design of product as well as improving the design including more customer oriented product features. This research has been designed to explore the possibilities.

The following two figures are related to the comparison of arm movement of excavator between two players. It has been introduced to figure out whether the difference can provide valuable information to the designer for improving the design or re-thinking about the current specifications. The trends of two figures are more or less the same. In figure 15, the comparison of arm movement between the winner and 14th placeholder has been analyzed. It is important to note that the arm movement has been calculated by measuring the distance between the center of main body and center of bucket. The difference of arm movement between these two players is clearly noticed from the figure. The range of arm movement by the winner is about 5 meters to 6.5 meters and the fluctuation is much more than the other player. On the other hand, the range of arm movement by the 14th placeholder is about 4.2 meters to 6 meters. The time and fuel consumption for the both players have been mentioned in table 6. Thus, the designer can conclude in a way that the increased arm length might be more effective for doing the regular job. The designer can also consider the ways of arm movement of winner as they guy used less time and less fuel consumption to finish the task.

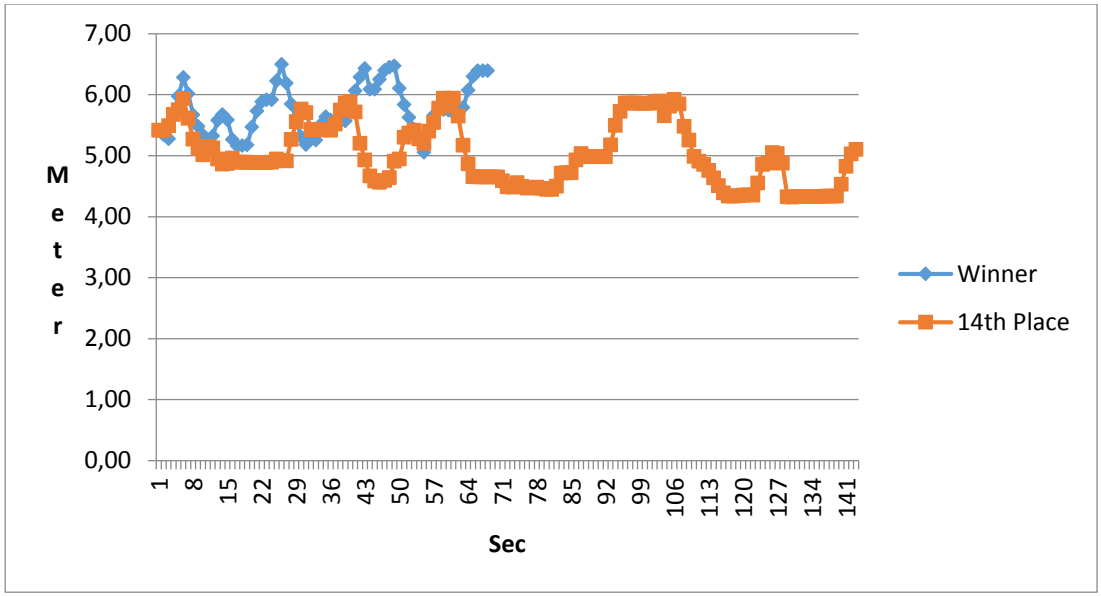

Figure 15: The comparison of arm movement (winner vs. 14th place)

Table 6: Time & fuel consumption of winner vs. 14th placeholder

Criteria	**Winner**	**14th place**
Time(s)	67.49	142.71
Fuel consumption(ml)	569.65	1191.86

From the figure 16, it is clearly seen that the difference of arm movement between the first runner-up and 15th placeholder is huge. The range of polynomial type graph for the arm movement by the first runner-up is about 5 meters to 7 meters, whether other player moved the arm from around 3 meters to 6.6 meters. The arm movement by the 15th placeholder is ranged mostly within 4 meters to 5 meters.

The fluctuation of arm movement is rapid but linear. This can also be helpful for designer to modify the length of arm accordingly. The time and fuel consumption for the both players have been mentioned in table 7.

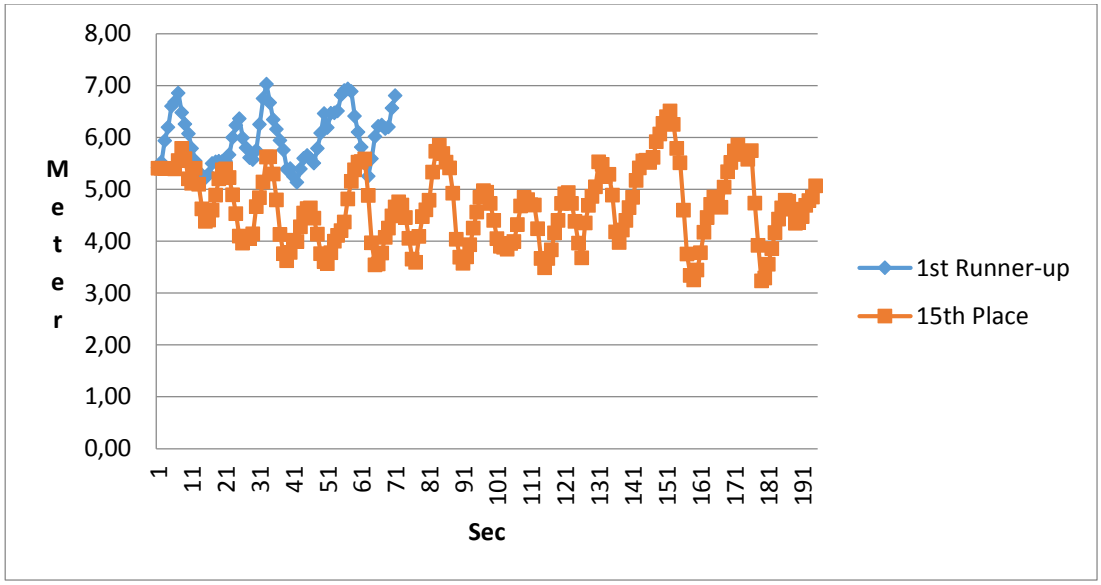

Figure 16: The comparison of arm movement (1st runner-up vs. 15th place)

Table 7: Time & fuel consumption of 1st runner-up vs. 15th placeholder

Criteria	**1st runner-up**	**15th place**
Time(s)	70.87	194.35
Fuel consumption(ml)	911.06	2247.55

Therefore, by using these kinds of analyses, the product designer and developer can make an understanding about their product and change the features accordingly.

Nevertheless, it has mentioned that, each player had to play the game three times. It has noticed that by changing the features of product, the performance of players has improved substantially. Here are two examples that might be important insights for the product development team to choose the best combination of features to the product.

The first example for the player (Daniel) and his game time and fuel consumption for the task are mentioned through figure 17 and table 8. From that table, it has been seen that in the first

attempt, he took 166.38 seconds and in the third attempt, he just took 103.97 seconds to complete the task. Moreover, he used around 1530 ml and 935 ml of fuel for the first and third attempts respectively. He used different types of hydraulic cylinders for the first and third time. The large bucket was used for each time and medium and small hydraulic cylinders were used accordingly. The arm speed improved due to selection of small hydraulic cylinder in the later phases. Thus, designer can check the combination and can come up with a solution of putting the best types of features for the product. For example, based on the virtual material handling such as sand used in this study, the more appropriate bucket should be big size and the hydraulic cylinder can be the small size.

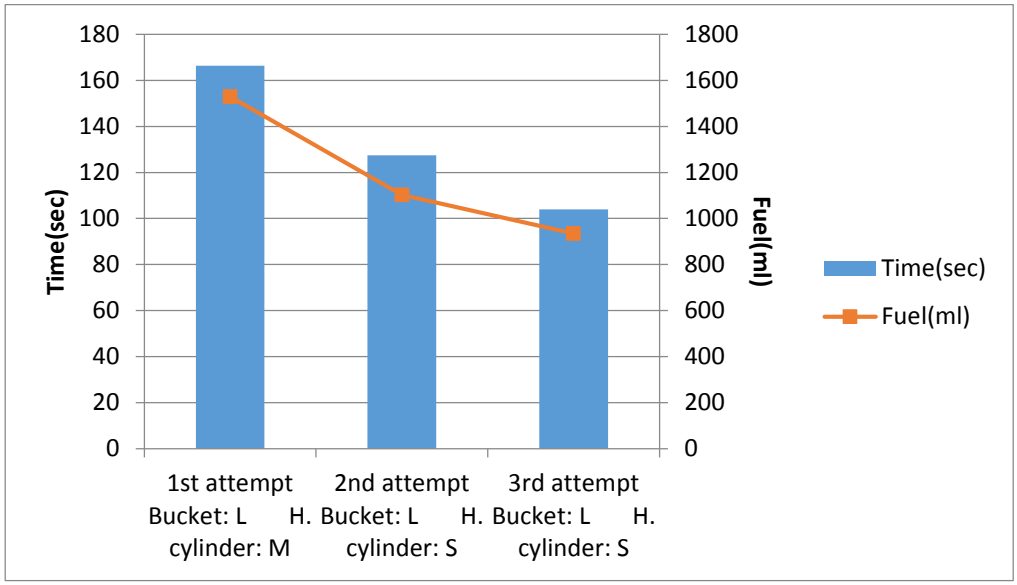

Figure 17: Changing product features improves performance of player (Daniel)

Table 8: Performance of player and product criteria over time for player (Daniel)

	1st attempt	**2nd attempt**	**3rd attempt**
Time(sec)	166.357	127.385	103.967
Fuel(ml)	1529.84	1102.91	935.2
Bucket	L	L	L
H. Cylinder	M	S	S

In the second example by the figure 18 and table 9, it has been seen that the performance of player (Kari) improved due to using the different combination of buckets and hydraulic cylinders for first and third attempts. The time and fuel consumption for the first attempt were 77.05 seconds and 994.02 seconds respectively and for the third attempt, the time reduced to 63.61 seconds and fuel consumption was about 859 ml. For the first time, he used medium bucket and hydraulic cylinder and in other two attempts, he used large size bucket and hydraulic cylinder, which definitely affected his performance.

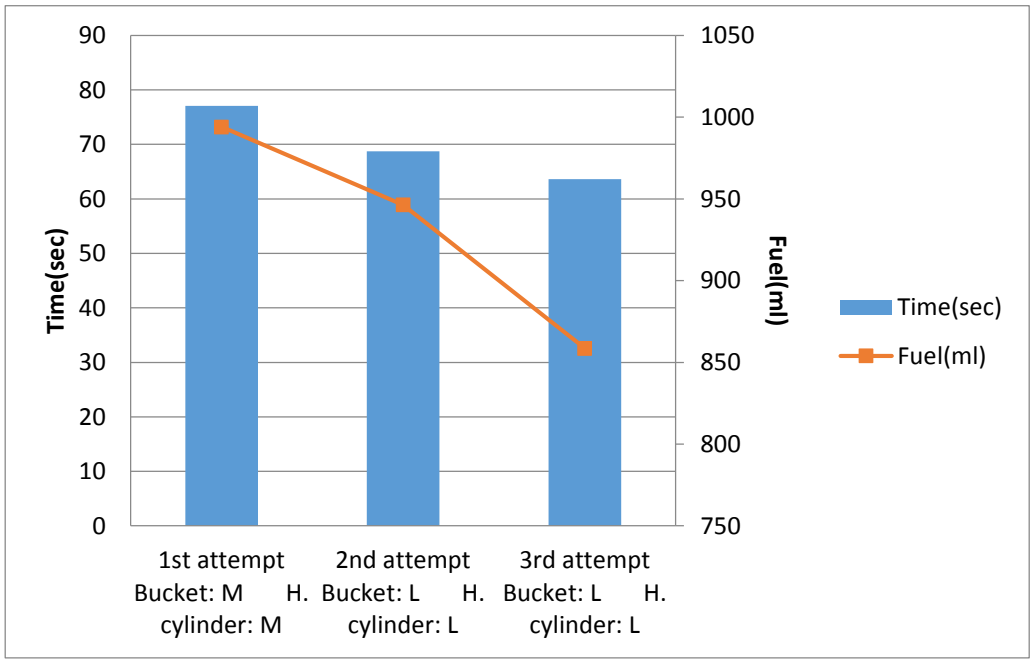

Figure 18: Changing product features improves performance of player (Kari)

Table 9: Performance of player and product criteria over time for player (Kari)

	1st attempt	**2nd attempt**	**3rd attempt**
Time(sec)	77.054	68.736	63.613
Fuel(ml)	994.02	946.39	858.57
Bucket	M	L	L
H. Cylinder	M	L	L

Therefore, it can be said that for this experiment, the changing of buckets and hydraulic cylinder have substantial effects on the player performance and it can be a possible approach by the designer to choose the appropriate features for the new product. In this study, bucket and hydraulic cylinder were the features could be changed by the player but for the bigger perspective, numerous features can be changed and gets valuable information by analyzing the data of gamification.

However, apart from these comparison of game data of players, some other important results have been gathered from the interviews. Thus, to answer the research question in more details, some additional questions have been formulated and answered accordingly.

- **What are the advantages and disadvantages of current product?**

In the interview, the players were asked about the features of the current excavator, they like and dislike. The following table 10 is the sum of these advantages and disadvantages based on the interviews for the both phase-1 and phase-2:

Table 10: Evaluation of existing product

Advantages	Disadvantages
❖ Flexibility and mobility of arm in different axes	❖ The excessive vibration
❖ Easy to dig and move the materials	❖ Control system could be more friendly
❖ Control system is fine and easy to understand	❖ Design of buckets should be updated
❖ Option to change different buckets	❖ The limited arm extension
❖ The safety features	❖ Limited views of surroundings

- **What particular features can be added to new product?**

The valuable insights can be gained from the users for the new product. As the players were introduced of the excavator through the virtually modeled excavator, thus they gave different new ideas of adding features to the excavator. The feasibility of adding the features was not the main point to get the information rather tried to get innovative ideas for the possible features. The ideas are listed as below:

- Adding cameras in different corners and small screen can be added in from of operator
- Introducing trunk to keep important stuffs
- Remote work through adding virtual reality
- Pre-programmed automated features for repeated works
- Include other tools for versatile works such as cutting tool
- Introducing innovative balancing system to work in different surface
- Laser technology for precious work
- Adding monitoring features like temperature, humidity, rain forecast

- **What could be the value of previous experience of players using the similar product for new product development?**

It has already mentioned that, there were six players from the company and they have the experience of using the real excavator in their current job. The next figure 19 shows the working experience of the six experience players:

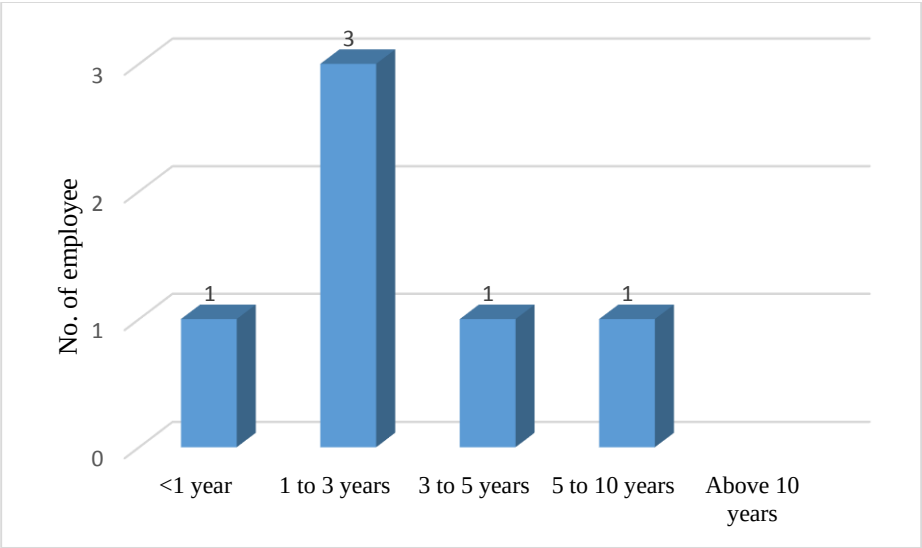

Figure 19: Work experience of employees

However, the frequency of using the excavator in their work differs a little. Some of them are using regularly and others are using occasionally. The below figure 20 denotes the frequency of using real excavator:

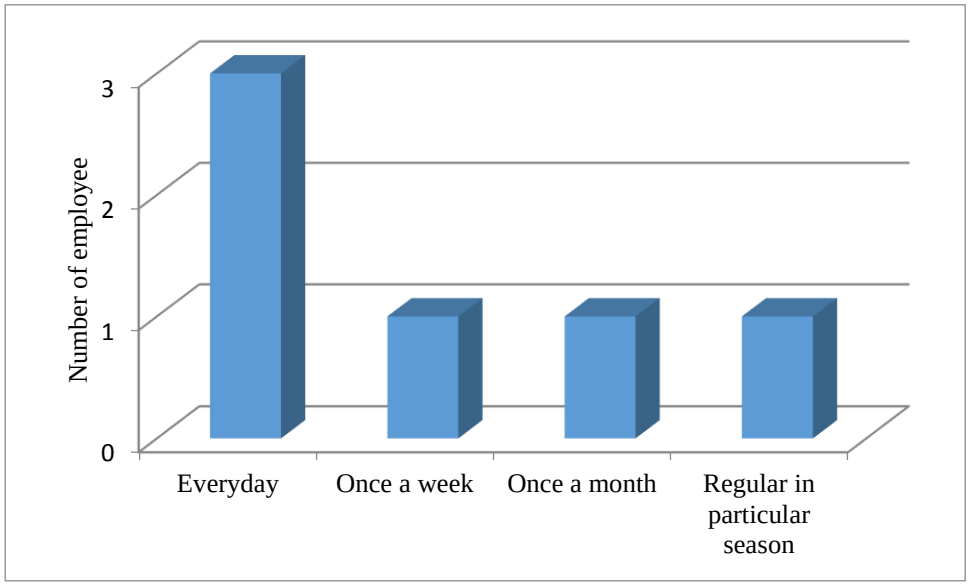

Figure 20: Frequency of using real excavator

By considering the experience of players, it has been seen that first runner up who has more than 10-year work experience in this field and who secured the fourth position has the experience of 3-5 years should be an indicator of having important value in product development. On the other hand, who use the excavator regularly are in first runner up, fourth and seventh position suggests the positive correlation of user experience in product design accordingly.

- **Is the existing product appropriate for doing particular task?**

The players could choose buckets from three different sizes and they were asked about the appropriateness of the bucket for their specific job. It was found that out of sixteen people, fourteen were said that the types and sizes were appropriate for their job and two persons disagree with this whether two other were on the both sides. The following figure 21 demonstrates the result. Amongst the three different sizes, the big bucker was the preferable for the most of the players. Players did not choose the small bucket because they thought it has very little comparative advantages over other two buckets.

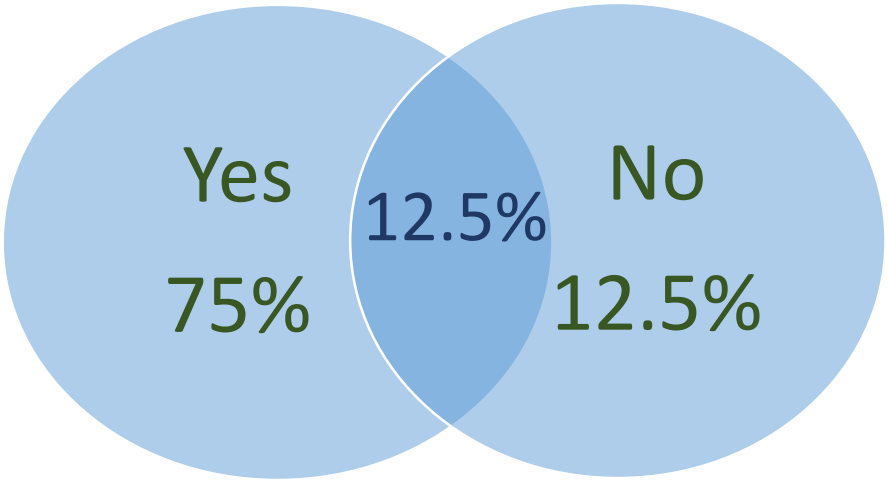

Figure 21: Appropriateness of buckets

The participants were also asked about the weight of bucket and the suggestion to improve the design of bucket. The effects of age range in new product development to get useful information are tried to find out. The results are mentioned in **Appendix 2**.

The hydraulic cylinder was another feature where the participants could choose different hydraulic cylinders along with the buckets. The main arm movement depends on the types of hydraulic cylinders. However, based on the choosing the hydraulic cylinders, the general feelings about the speed of arm movement was asked and majority found it quite fine for their assigned task. The result shows that amongst the six players who found the arm movement is not fast enough, three players were from the company, who have the experience of using real excavator regularly. Along with this, another issue was to find out the appropriateness of arm length of excavator. These two results are illustrated through the figure 22 and figure 23:

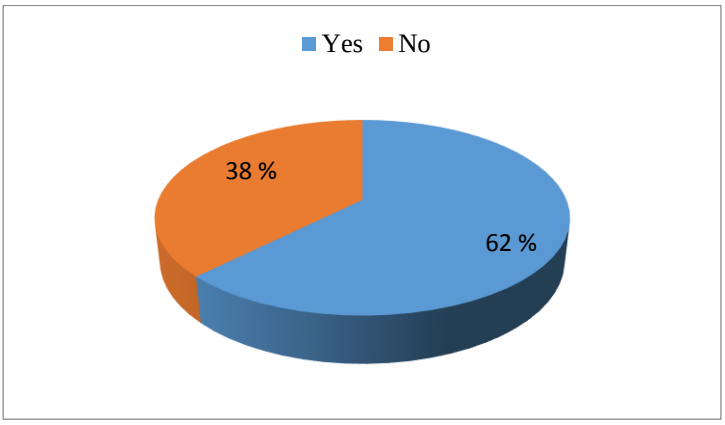

Figure 22: Fast movement of arm

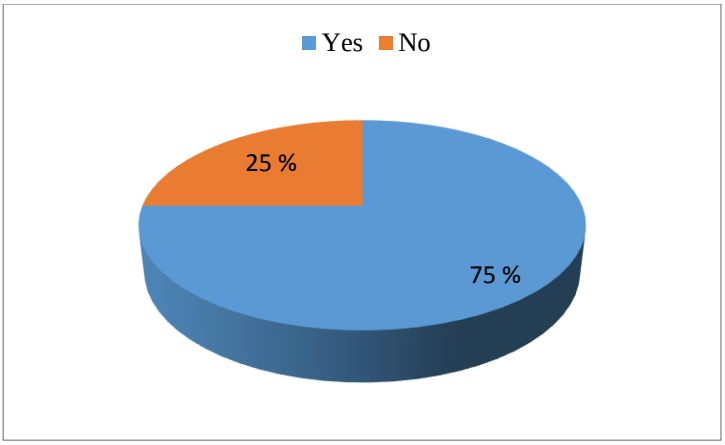

Figure 23: Appropriateness of arm length

Moreover, the players were also asked in the interview about what additional features, they want to have in the excavator. The view of players about the performance improvement of arm was also evaluated through interview. These two results have been provided in the **Appendix 2**.

R.Q. 2: What are the essential elements needed to have in gamification event using the virtual prototype model for new product development?

The components of game address the mechanics of game event. There are some important game components such as achievements means defined objectives, fights which denotes the hard challenges, leader-boards, points, badges etc. and fun is another important integral part of game (Werbach and Hunter, 2012). Moreover, the levels of game design elements have been mentioned in the section of elements of game introduced by Deterding et al. (2011). To judge whether this experiment has fulfilled the required criteria for the gamification or not, the relative comparison of elements in different levels is going to be demonstrated. The results from the interviews have been also depicted to validate the statement. The table 11 represents the components of this experiment in different levels.

Table 11: The scenario of different components of game

Levels	Example	In this experiment
Interface design	Leader-board, level	• The leader board is created based on different parameters and announced accordingly. • Due to make the event simple, the level of completion task was one.
Mechanics and design patterns	Resource limitation, Time constraint	• The player had to finish the task within certain period. • The limited fuel was another challenging criterion for the players. • Players had maximum change of hitting the obstacle 3 times.
Game principles	Clear goals	• The objectives of the playing were mentioned clearly before starting the game though the playing screen and verbally.
Game models	Challenges, fantasy, curiosity	• There were challenges in the game, the scenario has been depicted through the chart (figure 25) • Everyone was huge enthusiastic about the game. They like the game and it is illustrated through the figure 24.

The players were asked about their feelings of the gamification event. In the first phase of gamification, everyone said that they liked it. On the other hand, in second phase, 94% of players like the game and only 6% players did not like the gamification event. Their comments regarding the game include, it is very interesting with real life tasks, felt like real operator and new experience etc. The following doughnut chart by figure 24 depicts the result:

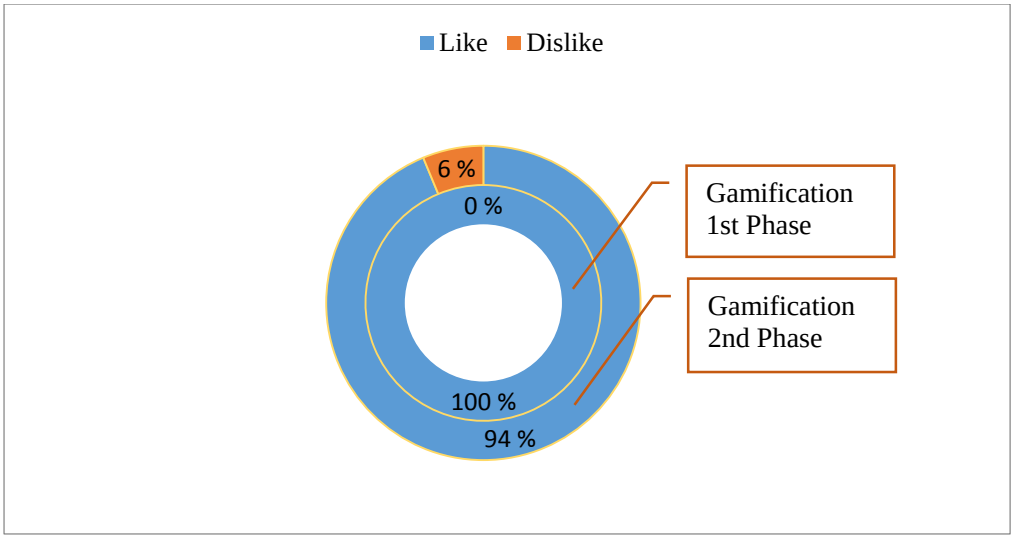

Figure 24: Opinion about the gamification

Challenge is another important game component and in the interviews, players were asked about it. From the first and second phase of game event, it has found that 83% and 62% players said that the task was very challenging and 17% and 38% did not face too much challenges playing the game respectively. The below figure 25 denotes the result:

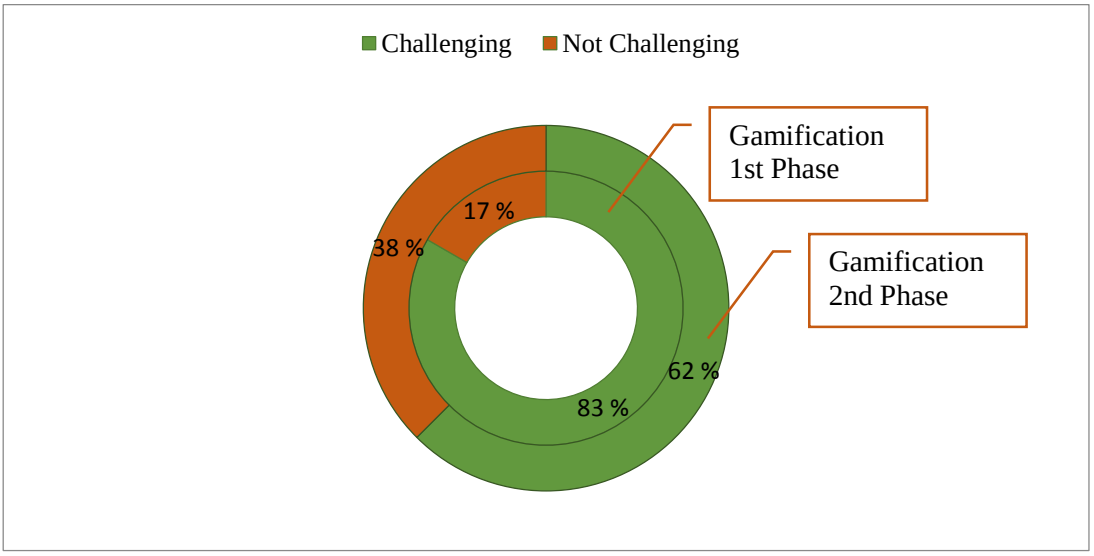

Figure 25: Viewpoint regarding the challenges

To concentrate on the goals, rules, players, it is easy to divert from the fun aspects. Additionally, to attract the players and to ensure the participation of the players repeatedly, the features of fun need to be included in the game (Werbach and Hunter, 2012). However, in this game event, fun plays an important role to make the event successful. It reflects from the result of interviews. The illustration of result shows in figure 26:

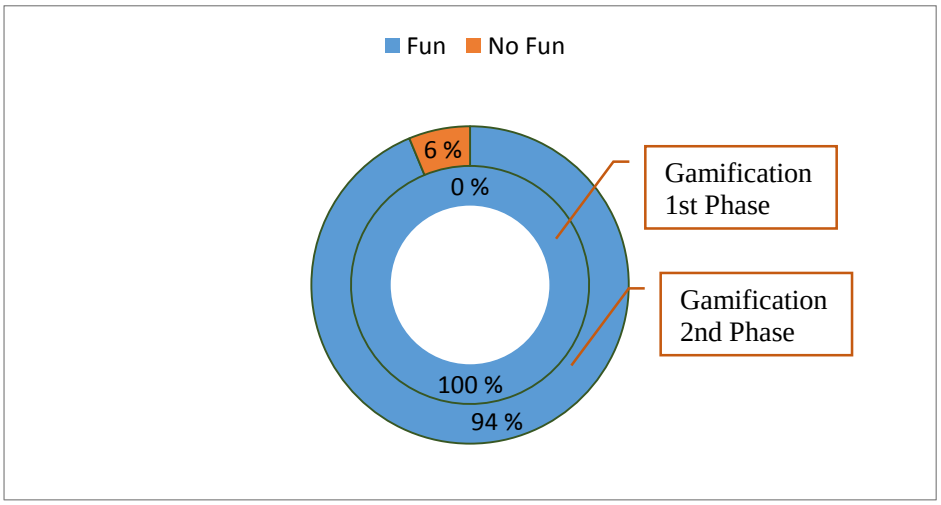

Figure 26: Opinion about the fun aspects

Everyone found the fun aspects in the first phase of gamification. On the other hand, in the second phase of gamification 94% players said that they enjoyed and it was funny whether 6% found little fun there. Moreover, there several other results from the interviews have been placed in **Appendix 2**.

5 DISSCUSSION AND CONCLUSION

The study aims to find out the possible outcomes of using virtual prototyping in product development through arranging a game event. The main objective was to figure out the ways by which product developer can utilize the user experience in new product development. To explore the options, virtual prototyping has been used in this research with arranging gamification event. Although virtual prototyping is not very new as a term but the applications of virtual prototyping in engineering design have been seen more frequently in recent years (Wang, 2002).

This experimental study is a unique type of work as no previous work has been found where incorporation of virtually modeled equipment like excavator with gamification event has been explored. This new type of research can be a possible dictation to the development of accomplishing more researches in similar arena.

The study is equipped with the previous literatures of concerned topics as well as the details of experimental process with possible outcomes from the exploratory study. Readers can get an idea about the needs of virtual prototyping in product development along with the direction of using it in new product development though a new means of way. However, at the initial stages of experiment, it was not easy for the author to make the whole structure to accomplish the study. There were few things needed to be considered starting the study such as getting the virtual modeled prototype of the particular product suitable for the experiment, which had been done by some other researchers collaborating with the software developer of the particular product. Later phase was to arrange the event of gamification in a way that can be effective to fulfill the objectives of this study.

In quest of answering the research questions, the game data as well as the semi-structured interview have been used. In order to find out the answer of first research question, the comparative advantages of using the product though different ways and performance improvement of users by changing various combinations of product features have been evaluated. The difference of arm movement by players has been shown in the section of data analysis and results. The comparison has been done intentionally between top scorer and low scorer of game. The efficiency level was better for the top scorers as they used less time and

fuel to complete the task. The fluctuation of arm movement for relatively top scorer than low scorer was more. Designer can think about the changing of arm length and freedom of movement according to analyze the data from such kind of comparison.

Moreover, performance improvement over time by choosing different features of product was another important prospect observed by analyzing the game data. It has already been mentioned that players had freedom to choose different combination of buckets and hydraulic cylinders in terms of size. It has been seen that most of the players improved their game performance gradually over the three attempts of playing; some examples have been depicted in data analysis and results section. Players like Daniel and Kari improved their performance gradually by choosing different sizes of buckets and hydraulic cylinders for their consecutive attempts of playing. It can be concluded that when the players used large size buckets, their performance became better than using medium size bucket as nobody used small size bucket considering the comparative benefit with other size of buckets. On the other hand, the small and large sizes of hydraulic cylinder have better effect to improve the performance of players. The product designer and developer have to figure out the right combination of product features analyzing these kinds of data from the gamification event.

It has been also found that the experience of users to use the similar product has positive effect to get valuable information to product designer. Moreover, numerous important insights have been found from the interviews such as the drawbacks of current product as well as innovative new features, which can be added to new product.

Effective use of user involvement in this experiment was one of the most important parts. Once the virtual prototype of excavator was ready to use, then the players for the event were chosen such a way to fulfill the objectives of the experiment accordingly. It has already mentioned that there were three types of players based on the previous experiment of using and playing game through virtual prototype. The challenging part was to communicate with the players from company as they can hardly speak English. Thus, the interview questionnaires were translated to Finnish and communication was done through interpreter.

Another important but challenging issue was the input of game elements in the design of virtual environment with the virtual excavator. Author had tested the virtual system in the platform before the event of gamification to endure the presence of game elements in the virtual environment and made several modifications according to the goals of experiment. The limited amount of fuel and hit with obstacle made the game more challenging and fun as well, which were set carefully to meet the aim of experiment.

This aim of this experimental study was not to provide the solution of particular fact rather to examine the results of particular phenomena and tried to make a bridge between the new product development and virtual prototyping by designing arranging a game event that might open a new door for further research. It has mentioned before that virtual prototyping has been using in product development in different fields but this introducing the gamification event makes the study unique. The outcomes from the experiment suggest that if the gamification has been added with virtual prototype of a particular product then, it can be an effective way to involve the users to get the valuable information for the new product development even for the modification of existing product.

5.1 Reliability and Validity of the Study

Reliability denotes to the extent that the techniques and analysis methods of data collections act in a way to generate consistent results over time similar to other events done by different researchers (Saunders et al., 2009, p. 156). In this study, the virtual prototype of standard crawler type excavator has been used, which can be used to other researches as well. The gamification event has been done with involving new and experienced users of the particular product, thus, it can be replicated as well. The participants' interviews were taken separately and in different times and dates by the author. Hence, this study reflects strong reliability.

Validity defines the findings are similar what they should be about. It is also related to the credibility of study (Saunders et al., 2009, p. 157). There might be a question about the validity of findings from the interviews as the numbers of interviewees were six and sixteen for the first and second phase of gamification respectively although involvement of professional personnel

along with new users suggests the validity of findings. Furthermore, the existence of important components of the experimental event to fulfill the objectives of study makes it valid accordingly.

5.2 Limitation and Future Work

The experimental study has been conducted based on virtual prototype of one specific product. The virtually modeled excavator was crawler type. Therefore, absence of possible findings for the other types of excavators and equipment will be a potential option for further study in this arena. The premise of arranging gamification is based on one particular location, which can be explored in different locations. Thus, different symposiums, trade fairs can be the places to arrange the game event for further exploration of this study. This kind of study can be more effective if experimental design will be done within a company by the employees for its existing or upcoming products. There are some risk factors involved with the experimental design. The wrongly designed game event might lead inappropriate and lack of information that can be harmful or wastage of time and cost as well. The involvement of virtual reality with the virtually modeled prototype will make the event more interesting and in a result, players can be involved remotely and online event will be the further extension for future study.

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APPENDICES

Appendix 1 Key Words Search

Key words: “Virtual Prototyping”

Database: *SCOPUS*

Search in Title, Abstract and Keywords: 6467 results

Subject Area “Engineering”, “Social Sciences”, “Computer Science”, “Business, Management and Accounting” & “Psychology”: 5351 results

Document type “Article”, “Conference paper”, “Conference review”, “Book chapter” and “Review”: 5269 results

Language “English”: 4837 results

AND “Product Development”: 1181 results

AND “Motivation”: 22 results

Key words: “New Product Development”

Database: *SCOPUS*

Search in Title, Abstract and Keywords: 109809 results

Subject Area “Engineering”, “Social Sciences”, “Computer Science”, “Business, Management and Accounting” & “Psychology”: 46390 results

Document type “Article”, “Conference paper”, “Conference review”, “Book chapter” and “Review”: 44894 results

Language “English”: 42174 results

AND “Simulation”: 5819 results

AND “Virtual Prototype”: 284 results

Key words: “Virtual simulation”

Database: *SCOPUS*

Search in Title, Abstract and Keywords: 75475 results

Subject Area “Engineering”, “Social Sciences”, “Computer Science”, “Business, Management and Accounting” & “Psychology”: 54312 results

Document type “Article”, “Conference paper”, “Conference review”, “Book chapter” and “Review”: 53729 results

Language “English”: 48425 results

AND “Product Development”: 3705 results

AND “Motivation”: 113 results

Key words: “Virtual Experiment”

Database: *SCOPUS*

Search in Title, Abstract and Keywords: 36946 results

Subject Area “Engineering”, “Social Sciences”, “Computer Science”, “Business, Management and Accounting” & “Psychology”: 26065 results

Document type “Article”, “Conference paper”, “Conference review”, “Book chapter” and “Review”: 25757 results

Language “English”: 23760 results

AND “Product Development”: 1294 results

AND “Motivation”: 112 results

Key words: “Gamification”

Database: *Web of Science*

Search in Title, Abstract and Keywords: 1488 results

Subject Area “Educational Research”, “Engineering”, “Business Economics”, “Social Sciences other topics” and “Behavioral Sciences”: 812 results

Publication period showed “from 2011 to present”: 812 results

Literature type “Proceedings paper”, “Book chapter” and “Article”: 793 results

Language “English”:756 results

AND “Motivation”: 246 results

AND “Product”: 8 results

AND “Product Development”: 3 results

Appendix 2 Some Results from the Interviews

Question: Do you think the bucket is heavier or lighter than required?

Answer: Players were asked about the weight of buckets and 62 said that it was either heavier or lighter than what they wished to be and on the other hand, 25% said the buckets were okay with 13 % had no comment. The percentages about the response show in following figure 27.

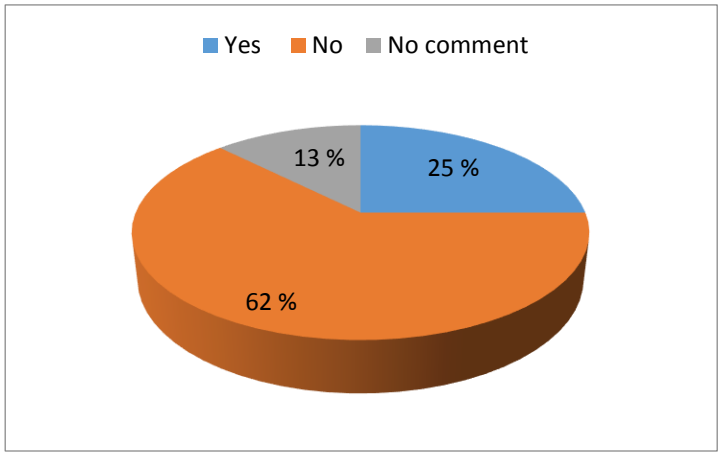

Figure 27: Buckets are heavier/lighter than required

Question: Do you have any particular suggestion to change the design of bucket?

Answer: The users provided some suggestions regarding the design improvement of buckets as mentioned below:

- The tips of bucket can be triangle shape
- Grab type bucket can be more effective
- Sharper edge of bucket tip can help to dig smoothly
- Width can be little more
- Circular type bucket
- Finger type bucket tips

Questions: Do you want to change or add any feature to arms?

Answer: The proposed new features from the interviewees are listed below:

- Additional cameras can be added
- The facility to extension of arm like crane arm
- The rotational option of arm can make it more flexible
- Water sprayer can be added in the tip of arm

Question: Do you have any suggestion to improve the performance of arms?

Answer: The list of feedbacks is depicted in below:

- The height of arm can be restricted to a certain lever for quicker work
- The arms could have more segments and angles for better work
- It might be more effective if can change the length of arm whenever it is needed.

Question: Do you think this kind of game could be useful for manufacturer to design more customer-orientated product? Please specify

Answer: The below list shows the insights of users regarding the asked question:

- Valuable information can be gathered
- Using for training and educational purpose of designer
- Finding out the possible faults or improvement area like ergonomics of product
- Pretest is possible for product
- Demands of market can be judged
- Customer usability can be tested

Question: The outcomes of gamification have positive impacts for design improvement of excavator. Please select your option.

Answer: About the question of having positive impacts for gamification, four players rated the gamification as 5 out of 5, whether six players marked it as 4. Moreover, five players rated it as 3 and one player rated as 2 with no 1 rating was found. The below figure 28 shows that maximum users said that the gamification should have positive impacts in design improvement.

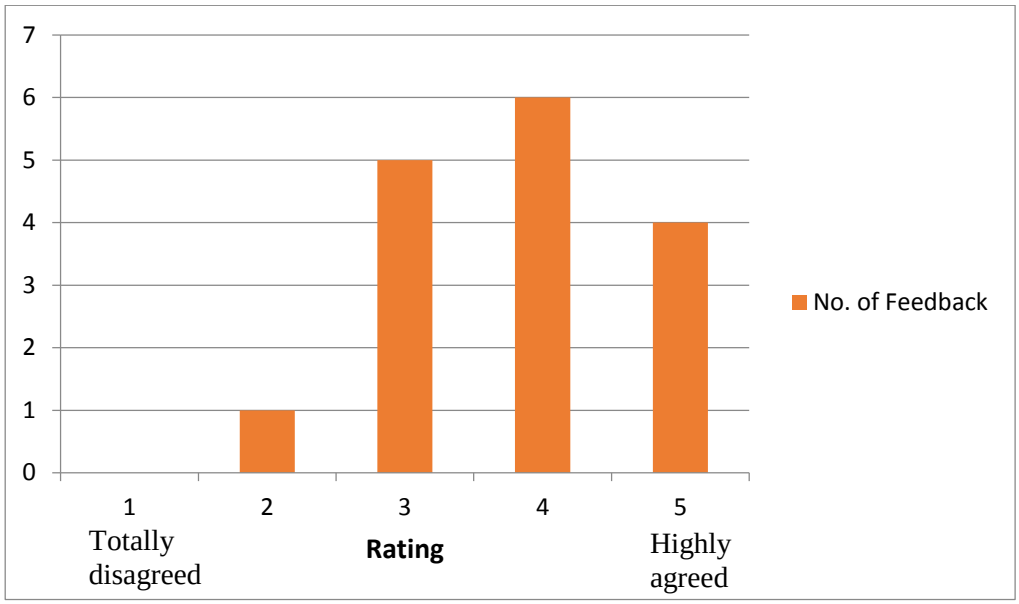

Figure 28: Positive impacts of gamification

Question: Is there any comparative benefit of certain age range to get fruitful information?

Answer: Morris and Venkatesh (2000) showed through their research that the age has substantial effect to adopt new technology such as younger users show more interest than older users to use new technology. In this study, effects of users' age have been evaluated by using virtual model of particular product through gamification. The ages of players who participated in second phase of gamification have been divided in four different ranges. The age ranges for the participants of first gamification have not been counted because all were about from 16 to 30 years old. The age range starts from 16 to above 50 for the second phase and the ranges are as in figure 29:

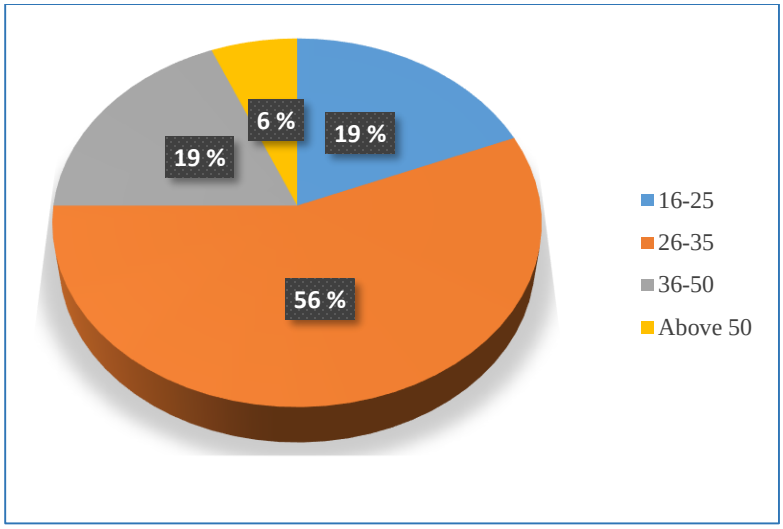

Figure 29: Age ranges of players

The majority of the players are in the age range of 26 to 35 and only 6% are in above 50-year. Interestingly, the winner and first as well as second runner-up are in the age range of 26-35 and one player who is above 50-year old secured his position as 15th out of 16th players. Thus, young users might have more influence in providing valuable information to product development.

Question: If you are interested to participate in the game, then how frequently, do you want to participate?

Answer: Players were asked about their interest of participating the game in future if will be invited accordingly. 27% of participants said, they wish to participate once in a month and 26% participants said that they wish to participate once a quarterly. The detail result is illustrated in following figure 30:

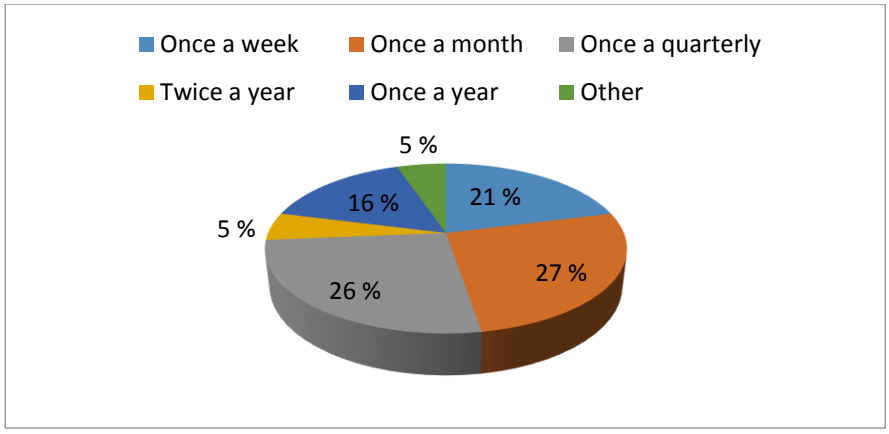

Figure 30: Interest to participate in game in future

Question: Do you have any suggestion or overall comments?

Answer: Some important feedbacks about the overall experience of participation in the event have been received from the interviewees. The list of comments sums as below:

- The game event was interesting and challenging, nice new experience.
- Arranging such game with the virtual prototype of upcoming product can be helpful for the company as it can reduce the cost and time to design the product as well as launching to market.
- As a game, received suggestions such as there should be more tasks, leader-board should be shown in screen, camera angle needs to improve, VR can be added which can make it more enjoyable.
- Training is important aspect for the product developer, safely can be ensured as using virtual model not physical product.

Appendix 3 Calculation of Making Leader-board (Gamification, phase 2)

	Players' Name		1st attempt												2nd											
			Bucket	Hydraulic cylinder	Fuel consumption		Hit	Time		Weighted score	Weighted score with proportion	Bucket	Hydraulic cylinder	Fuel consumption		Hit	Time		Weighted score	Weighted score with proportion
					ml	l		sec						ml	l		sec			
1	Sajib	18th Aug'17	L	M	795.05	0.79505	0	67.494	47.48432	49.85853	L	L	L	848.56	0.84856	0	68.516	48.21577	50.62656
2	Niko	17th Aug'17	L	M	911.06	0.91106	1	70.867	49.98022	52.47923	L	M	M	922.08	0.92208	0	76.134	53.57042	56.24895
3	Kari	17th Aug'17	M	M	994.02	0.99402	0	77.054	54.23601	59.65961	L	L	L	946.39	0.94639	0	68.736	48.39912	53.23903
4	Mikko	17th Aug'17	M	L	945.65	0.94565	0	96.472	67.8141	74.5955	L	M	M	828.3	0.8283	0	65.44	46.05649	50.66214
5	Simo	17th Aug'17	L	M	1266.71	1.26671	0	91.138	64.17661	70.59427	L	M	M	1070.41	1.07041	0	70.469	49.64942	54.61437
6	Sayed	17th Aug'17	L	L	829.81	0.82981	0	73.676	51.82214	51.82214	L	L	L	1204.53	1.20453	0	103.043	72.49146	72.49146
7	Janne	17th Aug'17	M	M	1282.44	1.28244	1	104.215	73.43523	80.77876	L	L	L	674.16	0.67416	0	56.827	39.98115	43.97926
8	Aleksi	17th Aug'17	L	L	1172.54	1.17254	0	88.711	62.44946	68.69441	L	L	L	1046.5	1.0465	0	79.124	55.70075	61.27083
9	Benkeltoum	17th Aug'17	L	M	1066.78	1.06678	1	94.807	66.78493	66.78493	L	S	S	1879.66	1.87966	0	154.656	108.8231	108.8231
10	Zheng	18th Aug'17	L	L	1428.49	1.42849	0	125.267	88.11545	92.52122	L	M	M	1172.09	1.17209	0	110.354	77.59943	81.4794
11	Mustafa	17th Aug'17	M	L	1263.33	1.26333	0	136.759	96.1103	96.1103	L	M	M	1333.65	1.33365	0	137.029	96.3204	96.3204
12	Farhad	18th Aug'17	L	S	1100.81	1.10081	0	125.035	87.85474	92.24748	L	M	M	1148.6	1.1486	0	132.904	93.37738	98.04625
13	Daniel	17th Aug'17	L	M	1529.84	1.52984	0	166.357	116.9089	116.9089	L	S	S	1102.91	1.10291		127.385	89.50037	89.50037
14	Mahmoud	17th Aug'17	L	M	1191.86	1.19186	0	142.714	100.2574	100.2574	L	L	L	1751.73	1.75173	3	164.083	115.6836	115.6836
15	Kimmo	17th Aug'17	M	M	2247.55	2.24755	0	194.352	136.7207	150.3927	L	L	L	1470.44	1.47044	0	107.87	75.95013	83.54515
16	Yan	17th Aug'17	M	M	Finished fuel	#VALUE!	1	316	#VALUE!	#VALUE!	M	M	n/a	#VALUE!	Max collision	236	#VALUE!	#VALUE!	#VALUE!

3rd											
Bucket	Hydraulic cylinder	Fuel consumption		Hit	Time						
		ml	l		sec	Weighted score	Weighted score with proportion	Average fuel used(L)	Average Time to finish task(Sec)	Avg. Weighted score	Avg. Weighted score with proportion
L	L	831.68	0.83168	0	62.39	43.9225	48.86791	0.825097	66.13333	46.54086	49.78
L	M	743.06	0.74306	0	55.122	38.80832	49.82564	0.858733	67.37433	47.45299	52.85
L	L	858.57	0.85857	0	63.613	44.78667	54.05466	0.932993	69.801	49.1406	55.65
L	L	1082.43	1.08243	0	66.532	46.89713	58.94816	0.952127	76.148	53.58924	61.40
L	L	1006.46	1.00646	0	74.384	52.37074	60.93882	1.114527	78.66367	55.39892	62.05
L	L	1100.79	1.10079	0	98.992	69.62464	64.64608	1.045043	91.90367	64.64608	62.99
M	L	1036.85	1.03685	0	93.383	65.67916	65.66836	0.997817	84.80833	59.69851	63.48
L	L	987.29	0.98729	0	68.756	48.42539	61.07772	1.068777	78.86367	55.5252	63.68
L	M	1464.05	1.46405	0	133.189	93.67152	89.75985	1.470163	127.5507	89.75985	88.46
L	S	1574.84	1.57484	0	157.427	110.6714	96.73518	1.391807	131.016	92.12874	90.25
L	L	1025.86	1.02586	0	101.884	71.62656	88.01908	1.207613	125.224	88.01908	93.48
L	L	1401.53	1.40153	0	150.748	105.9441	100.5117	1.21698	136.229	95.72539	96.94
L	S	935.2	0.9352	0	103.967	73.05746	93.15556	1.189317	132.5697	93.15556	99.85
L	M	1005.66	1.00566	0	95.698	67.2903	94.41043	1.316417	134.165	94.41043	103.45
L	L	1299.94	1.29994	0	93.557	65.87988	102.1352	1.672643	131.9263	92.85023	112.02
L	L	1114.92	1.11492	0	109.03	76.65548	#VALUE!	#VALUE!	220.3433	#VALUE!	#VALUE!

Appendix 4 Interview (As an example for new users)

Open your mind. LUT.
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Questionnairies for Gamification

Name of the Interviewer: *Md Iftekharul Islam*

Name of interviewee:

Occupation:

Mobile number:

Email:

Date:

1. How old are you?

- ○ 16-25 years old
- ○ 26-35 years old
- ○ 36-50 years old
- ○ More than 50 years old

2. How long have you been working in this company? (Only for company employees)

- ○ Less than 1year
- ○ 1-3 years
- ○ 3-5 years
- ○ 5-10 years
- ○ More than 10 years

3. Do you have any idea about gamification? (i.e. Gamification is *"the use of game mechanics and experience design to digitally engage and motivate people to achieve their goals"*)

- ○ Yes
- ○ No
- ○ A little

4. Have you ever participated in a game through simulator?

- ○ Yes
- ○ No

5. Have you ever used Excavator?

- ○ Yes
- ○ No

If yes, then what types of Excavator(s) have you used?

- ☐ 

Crawler

- ☐ 
Backhoe

- ☐

Suction

Dragline

- **Other excavators? Please specify ……..**

6. How frequently do you use this type of excavator? (Only for company employees)

- Everyday
- Once in a week
- Once in a month

- Regular in particular season
- Sometimes in particular season
- Other

7. Which features of crawler type excavator do you like most?

8. Which features of crawler type excavator you don´t like?

9. What particular features/parts do you want to add to the excavator?

10. What particular features/parts do you want to remove from the excavator?

11. Do you think the bucket(s) used in the excavator is appropriate for your task?

- Yes, Why?
- No, Why?

12. Do you think the bucket is heavier or lighter than required?

- Yes
- No
- Other

13. Do you have any particular suggestion to change the design of bucket?

14. Do you think the movement of arms is fast enough for your task?

- ○ Yes
- ○ No, any comment? _____
- ○ Other _____

15. Do you think the length of arm is appropriate to smooth work?

- ○ Yes, Comment? _____
- ○ No, Comment? _____
- ○ Other _____

16. Do you want to change or add any feature to arms?

17. Do you have any suggestion to improve the performance of arms?

- ○ Yes, Comment? _____
- ○ No

18. Did you like the game that you have just participated?

○ Yes, Why? _____

○ No, why? _____

19. Was it challenging?

○ Yes, comment? _____

○ No, comment? _____

20. Did you find any fun there?

○ Yes

○ No

○ A little

21. How real was the simulation of excavator and the environment?

	1	2	3	4	5	
Totally realistic	○	○	○	○	○	Totally unrealistic

22. Do you think this kind of gamification could have motivation aspect in your job?

- ○ Yes, Why? _____
- ○ No, Why? _____

23. Do you think this kind of game could be useful for manufacturer to design more customer orientated product? Please specify

_____

24. The outcomes of gamification have positive impacts for design improvement of excavator. Please select your option.

	1	2	3	4	5	
Totally disagree	○	○	○	○	○	Highly agree

25. If you are interested to participate in the game, then how frequently, do you want to participate?

- ○ Once in a week
- ○ Once in a month
- ○ Once in quarterly
- ○ Twice in a year

- Once in a year
- Own suggestion?

26. Do you have any suggestion to improve the game?

27. Overall comment?