**NTNU – Trondheim**
Norwegian University of
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# Gamifying an Oil-Gas-Water Separation Process in a Process Control System to Improve Operators' Motivation, Skills, and Process Understanding

**Marius Ludvigsen**
**Christian Wallervand**

Master of Science in Computer Science
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Supervisor: Alf Inge Wang, IDI
Co-supervisor: Ole Andreas Alsos, IDI
Kristoffer Husøy, ABB

Norwegian University of Science and Technology
Department of Computer and Information Science

**Sammendrag**

Serious games og relaterte fagfelt har i det siste fått mye oppmerksomhet på grunn av dets potensiale for bruk innen opplæring og undervisning. Serious games er (digitale) spill som blir brukt av andre grunner enn underholdning.

Gamification kan relateres til serious games og kan defineres som bruken av spilltankegang og spillmekanikk for å engasjere brukeren og for å løse problemer.

Iverksetteren av dette prosjektet var ABB. ABB leverer et prosesskontrollsystem som brukes til å kontrollere forskjellige prosesser på en oljeplattform. En av disse prosessene er å skille olje og gass fra vann. En simulator av denne separeringsprosessen ble utviklet for så og bli implementert inn i HawkEye, en prototype av det eksisterenede prosesskonotrollsystemet. Vi har samarbeidet med ABB for å "spillifisere" denne implementerte separeringsprosessen ved å bruke forskjellige spillmekanikker med sikte på å finne ut om gamification kan brukes til å forbedre en prosessoperatørs ferdigheter i forhold til prosessen, hans forståelse for prosessen og hans motivasjon. I et prosesskontrollsystem har en prosess høyest prioritet på grunn av prosessens alvorlighetsgrad. Dette betyr at de "spillifiserte" elementene ikke kan være påtrengende.

Den implementerte separeringsprosessen ble testet på to grupper på ti personer hver, de fleste av dem studenter. De to gruppene utførte separeringsprosessen to ganger, en gang uten de "spillifiserte" elementene og en gang med de "spillifiserte" elementene. Forskjellen mellom de to gruppene var i hvilken rekkefølge de utførte prosessen.

I etterkant av eksperimentet ble det foretatt en innsamling av data fra selve systemet, samt fra en spørreundersøkelse, en kunnskapsprøve og fra intervjuer som ble utført i forbindelse med testingen. Disse dataene ble analysert for å finne ut om den "spillifiserte" separeringsprosessen ga bedre resultater enn den "ikke-spillifiserte" separeringsprosessen. Resultatene fra eksperimentet viste at det ikke var noen forbedring i deltagernes ferdigheter med separeringsprosessen eller forståelse av den, men at de "spillifiserte" elementene hadde en positiv effekt på motivasjonen til brukere fra begge gruppene.

***Nøkkelord***: Gamification, serious games, prosesskontrollsystem, separasjon av olje og gass, simulator

**Abstract**

Serious games and its related fields have lately received a lot of interest due to their potential for training and education. Serious games can be defined as (digital) games that are used for reasons other than entertainment.

Gamification can be related to serious games and can be defined as the process of game-thinking and game mechanics to engage users and solve problems.

The initiator of this project was ABB. ABB delivers a process control system used to control the processes of an oil production facility. One of these processes is separating oil and gas from water. A simulator of this separation process was developed and then implemented into HawkEye, a prototype of the existing process control system. We have worked with ABB to gamify the implemented separation process using different game mechanics to discover whether gamification can be used to improve a process operator's skills, understanding, and motivation. In a process control system, the process at hand has the highest priority due to its severity, which means that the gamified elements have to be subtle.

The implemented separation process was tested on two groups consisting of ten people each, most of them students. The two groups carried out the separation process twice, one time without the gamified elements and one time with the gamified elements. The difference between the two groups was in which order they did the separation process.

After the experiment, data was gathered from the implemented system, and also from a survey, a quiz and interviews that we conducted. These data were analysed to determine if the gamified separation process yielded better results than the non-gamified separation process. Results from the experiments showed that there was no improvement in the participants' skill or understanding because of gamification, but that the gamified elements had a positive effect on both groups' motivation.

***Keywords***: Gamification, serious games, process control system, oil and gas separation, simulator

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We also want to thank our family and friends for their support and love during this project. Especially we would like to thank those that dedicated their time to assist us.

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# Chapter 1

# Introduction

Serious games is a relatively new research area (2011), but has already raised much attention regarding training and education[3]. Serious games are (digital) games that are used for reasons other than entertainment[30]. More detailed information and definitions on serious games can be found in Chapter 2: Background.

Gamification is a term that can be related to serious games. Zichermann and Cunningham defines gamification as *"the process of game-thinking and game mechanics to engage users and solve problems"*[37, p. xiv].

The initiator of this project was ABB which delivers a process control system, System 800xA, used to control the processes of an oil rig, or oil production facility. One of these processes is separating oil and gas from water. A simulation of this separation process was developed and implemented into HawkEye, a prototype version of the existing System 800xA. Serious games and gamification was combined to gamify the implemented separation process to determine whether a gamified separation process can increase a process operator's motivation, skills and understanding. The next section introduces the separation process.

## 1.1 The separation process

An oil well is an underground repository that mainly consists of three different components; crude oil, gas, and water. An oil rig, or an oil production facility, is used to drain oil wells and separate the three different components (crude oil, gas, water) from each other to produce some marketable products, i.e. oil and gas[26].

The above-mentioned separation process, which was gamified, is based on a three-phase gravity separator[26]. The separator is divided into two

sections; the separator tank and the oil tank. These two sections are separated by a vertical wall, see Figure 1.1.

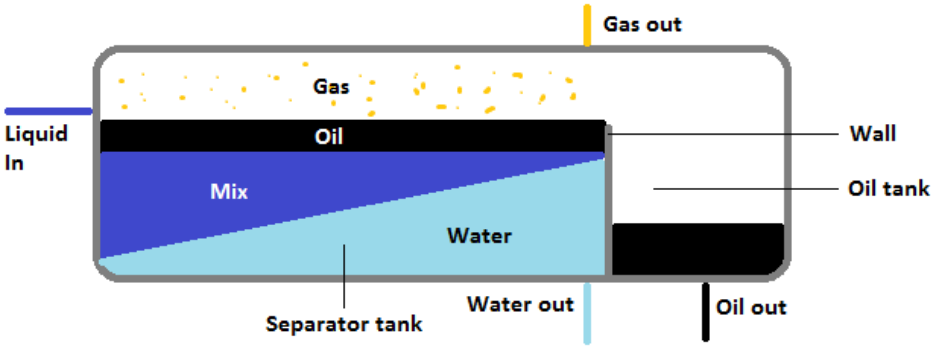


Figure 1.1: Illustration of the separator

The mixed fluid drained from the oil well first enters the separator tank. In the separator tank, oil, gas, and water will be separated by gravity and thereafter form three layers[26]. The oil will separate from the water and form a layer of oil that floats on top of the water. Gas will then rise to the top of the tank.

The goal of the implemented separation process is for the process operator to produce as much oil and gas as possible with the highest quality possible. Oil quality is affected by how much water is in the oil, gas quality is affected by the gas pressure.

The separation process is controlled by opening or closing four different valves, see Figure 1.1. One valve (liquid in) is used to control the inlet of mixed fluid that enters the separator tank, another valve (water out) is used to drain fluid (i.e. water) from the separator tank, a third valve (oil out) is used to drain fluid (i.e. oil) from the oil tank and a fourth valve (gas out) is used to control the pressure in the tank. The latter is directly related to the gas production. Opening or closing any of these valves will affect the pressure in the tank, which affects the production and the quality of gas.

The separation process explained here (and implemented in the system) is a simplification of the real-life separation process, meaning that some factors have been excluded (e.g. that the fluid can contain sand and pebbles). In this thesis "separation process" refers to the simulated oil and gas separation process that was developed and implemented into HawkEye.

## 1.2 Gamifying the separation process

In order to improve the operator's skills, understanding, and motivation several game mechanics were implemented.

A *tutorial* was implemented to train the operator. It is the only implemented game element that is used in both the gamification version and the non-gamification version of the separation process. The operator is awarded *score points* as he produces oil or gas. Scoring is a form of motivation which Dantas, Barros, and Werner describes as one of the keys for educational success[9]. The operator's score is accessible in a *high score list*. The goal of the high score list is to motivate the operator to perform better. In addition to score points the operator is awarded with *experience points* for his production and performance, which affects the operator's rank. *Ranking* is a form of motivation. Another motivational game element that was used are *goals*. The main goal of the separation process is to produce as much oil and gas as possible with the highest quality possible, in a given amount of time. In addition to this main goal sub-goals were added to the separation process. When completing a goal the operator is rewarded with score points and experience points. A *reward/penalty system* is used to reward or punish the operator (using score points or experience points) based on his actions and performance. The *feedback system* uses the reward/penalty system to provide the operator with informative feedback. The goal of the feedback system is to serve as a tool for improvement of the operator's skills and understanding by providing information about the operator's actions. At the end of the gamified separation process the operator is presented with a *summary* of his performance. The goal of the summary is for the operator to learn from his actions and performance. Annetta, Lamb, and Stone states that informed learning can occur if a *"summative, after-action review is provided for the player"*[2, p.80]. Table 1.1 summarizes the purpose of each game element.

| | Motivation | Skill | Understanding |
|---|---|---|---|
| Tutorial | | | X |
| Score points | X | | X |
| High score list | X | | |
| Experience points | X | | |
| Ranking | X | | |
| Goals | X | | |
| Reward/penalty system | | X | X |
| Feedback system | | X | X |
| Summary | | | X |

Table 1.1: Purpose of the game elements

## 1.3 Research questions and goals

A lot of research has already been conducted on serious games (and its related fields), but no research has been conducted on gamification in a process control system. The processes being run through ABB's system are of great severity and serious damage can occur if something goes wrong. For this reason it is important that the use of gamification is subtle. The user interface must be clean, informative, and minimalistic. With this in mind we wanted to answer three research questions:

**RQ1:** *Can a gamified separation process improve an operator's motivation?*

Does gamification motivate an operator to do a better effort in his job, and is the separation process more fun to perform with gamification?

**RQ2:** *Can an operator's skills be improved by gamification?*

Can gamification help the operator to do a better job, i.e. produce as much oil and gas as possible with the highest quality possible?

**RQ3:** *Can gamification improve an operator's understanding of a given subject?*

Will gamification help the operator to gain a better understanding of the task domain, i.e. will the operator get a better understanding of the separation process?

## 1.4 Method

To conduct the research an empirical method discussed by Victor R. Basili[4] was used. We created an experiment which was tested on N = 20 participants divided into two groups consisting of ten participants each. Each participant was first given a verbal explanation of the separation process, followed by a game tutorial of the separation process. Both groups carried out the separation process twice, once with gamification and once without gamification. What distinguished the two groups from each other was whether they carried out the separation process with or without gamification first. After the tutorial, the separation process was executed for the first time (with or without gamification). After this first run, each participant answered a quiz before they tried the separation process for the second time (with or without gamification). When the second run was concluded each participant answered a survey before being interviewed. When the experiment was done data was collected from the system created, the quiz, the survey, and from the interviews.

Figure 1.2 shows how the experiment was conducted for each participant. For a more detailed explanation of the experiment, we refer to Section 5.3: Research design.

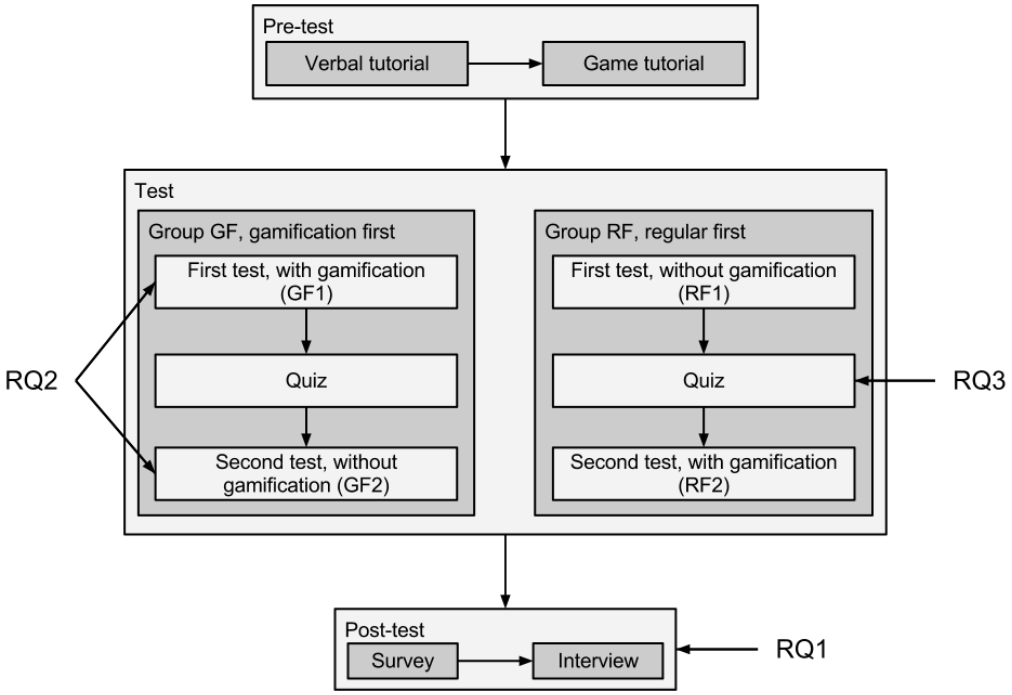


Figure 1.2: Experiment flow

### 1.4.1 Data from the system

The application logs its own state (i.e. produced oil, oil quality, produced gas, gas quality, etc.) each second as well as when valves are opened or closed. To answer RQ2, data from the first run of the two groups was compared to see if the gamified separation process improved the participant's performance. Data from the first and the second test run of each group was also compared.

### 1.4.2 Data from the quiz

The quiz asked the participants questions related to the separation process. The goal of the quiz was to see if the gamified separation process improved the users understanding of the separation process, i.e. to answer RQ3. The quiz can be found in Appendix D.

### 1.4.3 Data from the survey

With the survey we wanted to examine what each participant thought of the gamified process. The survey asked questions related to the user interface,

gameplay, comparison between the gamified separation process and the non-gamified separation process, and system usability. Data collected from the survey was used to answer RQ1 and partially RQ3. Questions asked in the survey can be found in Appendix B, results from the survey can be found in Appendix C.

### 1.4.4 Data from the interview

The interview was the last part of the experiment. Data collected from the interview was used to answer RQ1 and partially RQ3. Questions asked in the interview can be found in Appendix E.

## 1.5 Thesis structure

This report is structured into 8 chapters. This chapter introduces the thesis. *Chapter 2: Background* presents previous research and definitions of terms that are relevant to this thesis in addition to explaining the separation process. *Chapter 3: Game concept* explains how a game concept was designed for this project. *Chapter 4: Implementation* describes how the created game concept was implemented. *Chapter 5: Research questions and method* presents our research questions, the research method used, and the design of the research. *Chapter 6: Results* presents the results of the experiment. *Chapter 7: Discussion* considers the implications of the results from Chapter 6. *Chapter 8: Conclusion and further work* concludes this report by summarizing the thesis and suggests further work and improvements.

# Chapter 2

# Background

In 2006 the digital gaming market was a $10 billion per year industry, and in 2007, as stated by Ben Sawyer (co-founder of the Serious Games Initiative), the serious games market was at $20 million and expected to grow over the next decade[30]. In 2010 the serious games market was worth 1.5 billion euros[1] cited by Djaouti, Alvarez, Jessel, and Rampnoux[11]. There is also the global education and training market which was at $2 trillion per 2003[20, p. xvi]. This indicates that there is a growing demand for research and development in serious games.

We will in this chapter present some of this research. We provide information on serious games and related fields, we present definitions, previous research, and existing solutions. In addition we explain the separation process in more detail.

## 2.1 Definitions

Our game concept is related to several research areas; gamification, serious games, educational games, game based learning and edutainment being the most relevant ones. In this section we introduce definitions of these research areas.

### 2.1.1 Gamification

Gamification is the union of all the different advancements in games for non-gaming contexts[37, p. xiv]. Zichermann and Cunningham defines gamification as *"the process of game-thinking and game mechanics to engage users and solve problems"*[37, p. xiv].

### 2.1.2 E-learning

Tzeng, Chiang, and Li provides the following description of E-learning: *"E-learning combines education functions into electronic form and provides instruction courses via information technology and Internet in e-Era"*[32].

### 2.1.3 Edutainment

Edutainment is education through entertainment and was popular during the 90s due to the growing multimedia PC market[20, p. 24]. The term refers to any form of education that also seeks to entertain[30] and is not limited to video games[20, p. 24], though it is usually associated with video games that aims to educate[30].

### 2.1.4 Serious games

Serious games is often defined as *"(digital) games used for purposes other than mere entertainment"*[30] and they *"usually refer to games used for training, advertising, simulation, or education that are designed to run on personal computers or video game consoles"*[30]. Kevin Corti, founder of PIXELearning Limited, states that serious games *"is all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills"*[8].

According to Susi, Johannesson, and Backlund many websites describe serious games as *"wanting to achieve something more than entertainment"*, and these websites consider serious games more of a movement than a defined area of its own[30].

Michael Zyda's definition is similar to the descriptions provided above, though more formal:

> *"Serious game: a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives"*[38].

Zyda also explains that serious games contain more than story, art, and software, which by experience is the main components of a digital game for entertainment. The extra element is that of pedagogy: *"activities that educate or instruct, thereby imparting knowledge and skill"*. It's the addition of pedagogy that makes games serious, however, Zyda states that entertainment comes first[38].

Michael and Chen states that serious games are games that *"do not have entertainment, enjoyment, or fun as their primary purpose. That isn't to say that the games under the serious games umbrella aren't entertaining, enjoyable, or fun. It's just that there is another purpose, an ulterior motive in a very real sense"*[20, p. 21]. Michael and Chen's definition stands in contrast to Zyda's opinion which puts entertainment before pedagogy.

Susi et al. define serious games as *"games that engage the user, and contribute to the achievement of a defined purpose other than pure entertainment (whether or not the user is consciously aware of it)"*[30]. They point out that *"a game's purpose may be formulated by the user her/himself or by the game's designer, which means that also a commercial off-the-shelf (COTS) game, used for non-entertainment purposes, may be considered a serious game"*[30].

### 2.1.5 Game-based learning (GBL)

Game-based learning (GBL) is considered *"a branch of serious games that deals with applications that have defined learning outcomes"*[35]. Some people consider serious games and GBL the same[30], e.g. Kevin Corti[8]. Digital game-based learning (DGBL) is closely related to GBL, except that DGBL is restricted to digital games[30].

## 2.2 Previous Research

Serious games is a relatively new research area, but it has already raised much interest regarding training and education[3]. This interest is because of serious games' ability to *"capture players' attention and concentration for long periods of time, which is one of the biggest struggles for teachers or parents in terms of education"*[3]. In general, serious games are proving to be valuable assets for both teaching and training in various industries[3]. Additionally, *"a majority of people believe that games are engaging, that they can be effective, and that they have a place in learning"*[12].

We present a selection of the existing research according to our research questions. In addition we present information on important game mechanics for learning.

### 2.2.1 Motivation

According to Freitas and Jarvis, early indications in the literature demonstrate that technology-based simulations and game-based learning show some

initial evidence of accelerating learning, increasing motivation and supporting the development of higher order cognitive thinking skills[10]. They believe that this evidence, coupled with a generational acceptance of games as a significant part of everyday life has led to a wide interest in how games, in particular immersive digital games, can be applied effectively in learning contexts[10].

### 2.2.2 Skill

In 2005 an algebra game called Dimenxian was evaluated to determine the learning effectiveness of the game. 75 students participated in the study playing Dimenxian and results from the study showed that Dimenxian increased students' algebra grade by one level[18].

According to Sliney, simulation programs for medical training have resulted in *"improved performance, shorter response time, and less deviation from practice standards than non-simulator training."* Sliney also states that medical simulators increase the confidence and competence of the trainee in addition to improve a patient's safety[28].

### 2.2.3 Understanding

In a study conducted by Squire, Barnett, M. Gant and Higginbotham[29], a middle school class was divided in two groups, one control group and one experimental group. Both groups were to learn electrostatics. The control group was taught electrostatics through interactive lectures, observations, and demonstrations. The lecture was designed by the teacher. The experimental group played a game called SuperCharged! (an electromagnetism simulation game developed in consultation with MIT physicist John Belcher) and was given supplemental materials and interactive lectures from the same teacher. Before and after the study the students had to answer an exam on electromagnetism. Results from the study showed that the control group of 32 students had a 15% increase in their understanding of the material they had been taught. The experimental group, of 58 students, had a 29% increase in their understanding of the material being taught[29].

Mayo describes a study[19], cited in [18], where the learning outcomes between traditional lectures, Web-based experiences, and immersive games, are compared. The immersive games, in particular, was a virtual world-based geology game called Geography Explorer and a virtual world-based game called Virtual Cell. The research showed that Geography Explorer increased the learning outcome by 15% - 40% and that Virtual Cell increased

the learning outcome by 30% - 63%, both compared to the traditional lecture.

### 2.2.4 Important game mechanics for learning

Although research on games for education and training have shown positive effects on motivation, skills, and understanding, these effects do not come by themselves. Games for training and education purposes need to incorporate certain qualities for them to be effective learning or training tools[18].

According to Mayo, learning science has begun to isolate the kinds of instruction that lead to improved learning outcomes, he points at some of them and their application to video games[18]:

- ***Experiential learning ("If you do it, you learn it")***
  A common mode of instruction in the video game domain. Players navigate game scenarios and make decisions which have consequences.

- ***Inquiry-based learning ("What happens when I do this?")***
  A well-regarded philosophy among science and math educators. It is also a natural mode for many video games where free-form exploration, discovery and experimentation are encouraged in pursuit of an overall game goal.

- ***Self-efficacy ("If you believe you can do it, you'll try longer/harder, and you'll succeed more often than you would otherwise")***
  Points, levels, or magic swords are awarded at positive decision points, which encourage the player to keep playing. As stated by Michael and Chen, high scores can be a source of bragging for the player[6, p. 3].

- ***Goal setting ("You learn more if you are working toward a well-defined goal")***
  All games have goals, this is a key distinction between games and simulations.

- ***Cooperation (team learning)***
  MMOGs are intrinsically structured as a team effort toward a common goal. Studies of classroom techniques show that cooperative learning has about a 50% improvement compared to either solo or competitive learning[16] cited in [18].

- ***Continuous feedback, tailored instruction, cognitive modelling***

> For games to be able to teach or train, they should give continuous feedback on user performance, automatically adjust the learner experience based on learner response, and use cognitive modelling with respect for how to present, order, and emphasize the material to be learned.

Self-efficacy and goal setting are forms of motivation. Motivation is according to Dantas et al. one of the keys for educational success[9]. Susi et al. also states that *"games should be engaging and motivating"*, which is advantageous for e.g., *"the development of a variety of skills and abilities"*[30].

Michael and Chen highlights the importance of appropriate feedback, regarding the assessment of serious games[6]; *"an important feature of this built-in assessment is the way the game adapts to the player's behaviour and gives the player the appropriate feedback. Players come to understand the connection between their in-game actions and the outcomes"*[6]. Kevin Corti states that *"assessment starts pre-game"*, and that it *"runs all the way through the game and continues after the game"*[6]. Similarly, Annetta et al. states that *"informed learning can only occur if both in game feedback is given and a summative, after-action review is provided for the player"*[2, p. 80].

If a game is to provide appropriate feedback and also be engaging and motivating, these mechanics should be incorporated by the game's development team.

Additionally, domain knowledge is needed. Reidel and Hauge conducted an analysis of serious games for industry and business in 2011, in which they concluded that *"serious games are context dependent and require subject knowledge for their development"* and that *"they need facilitation by human facilitators in order to get the best learning out of them, although they can be used stand-alone"*[25].

## 2.3 Existing solutions

This section presents existing commercial solutions and solutions for research purposes. We did not find research on any existing solutions that can be compared to our solution. The reason for this could be explained by Reidel and Hauge, which state that they had a hard time retrieving information on serious games developed and used by educational and vocational training institutes. They claim that the use of a game is often a competitive advantage, and that the market for serious games is very fragmented as a lot of universities develop their own games for teaching purposes, and many of the commercial developers are small and medium sized enterprises, developing solutions only available to single customers[25].

### 2.3.1 Existing commercial solutions

#### Google A Day

Google A Day is a puzzle game developed by Google. The game presents a new question each day which the player will have to answer. The player's goal is to find the correct answer as fast as possible (using the Google search engine). The goal of the game is to teach the player how to use the Google search engine in the most effective way. We categorize this game as an educational game by means of gamification.


Figure 2.1: Google A Day

The player is provided by a "Tips & Tricks" tool (seen in Figure 2.1), as well as hints and the correct answer if desired, as seen in Figure 2.2.

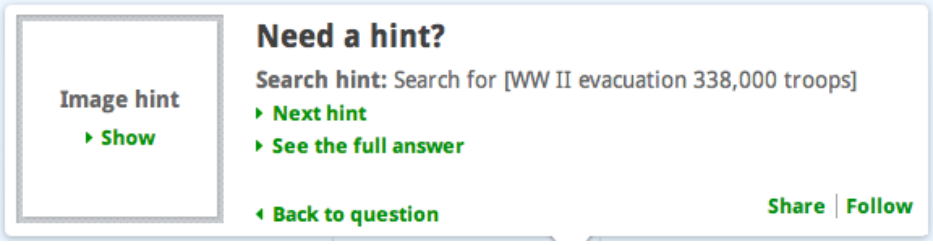


Figure 2.2: Hint in Google A Day

A timer indicates how well the player is performing by using colours, see Figure 2.3.

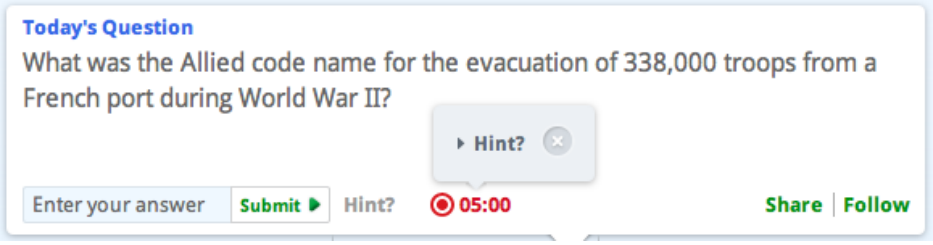


Figure 2.3: Google A Day red timer

### Ribbon Hero 2

Ribbon Hero 2 is a game for learning Microsoft Office, developed by Microsoft. The goal of the game is to teach the player how to use the different tools provided in the Office package. Ribbon Hero 2 is set in different eras (Middle Ages, Ancient Egypt, etc.), promoting how to learn to work with e.g. hieroglyphs, see Figure 2.4. The player is given points based on the difficulty of the task and how many hints the player used to complete the task, see Figure 2.5. We categorize Ribbon Hero 2 as an educational game by means of gamification.


Figure 2.4: Ribbon Hero 2 displaying the Ancient Egypt era with multiple tasks

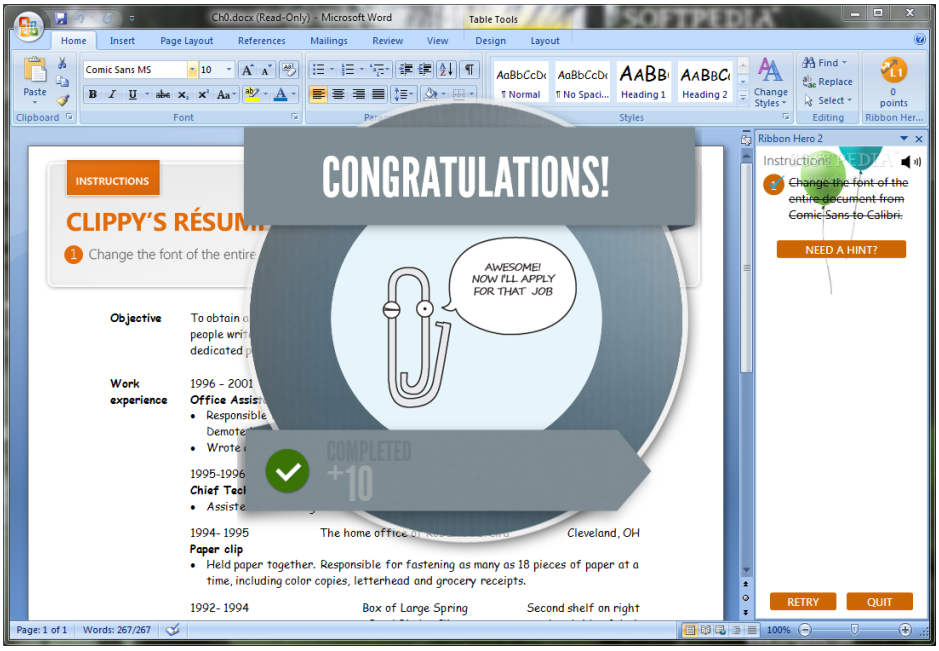


Figure 2.5: Ribbon Hero 2 score

### Dr. Kawashima's training games

The Dr. Kawashima franchise is a game franchise which is developed for the Nintendo DS, DS Lite, DSi, DSi XL and Nintendo 3DS. The franchise consists of the games Brain Training: How Old Is Your Brain?, More Brain Training: How Old Is Your Brain?, Maths Training: The Hundred Cell Calculation Method, and Sight Training: Enjoy Exercising And Relaxing Your Eyes. Not all of these games bear the Dr. Kawashima title.

The goal of these games is to train and stimulate the player's brain (and sight) in different fields (memory, math, counting, reading out loud, etc.)[23]. Figure 2.6 and Figure 2.7 show examples of tasks that the player is presented with. The games in the Dr. Kawashima franchise are COTS games sold in regular consumer electronics stores. We categorize them as educational games.

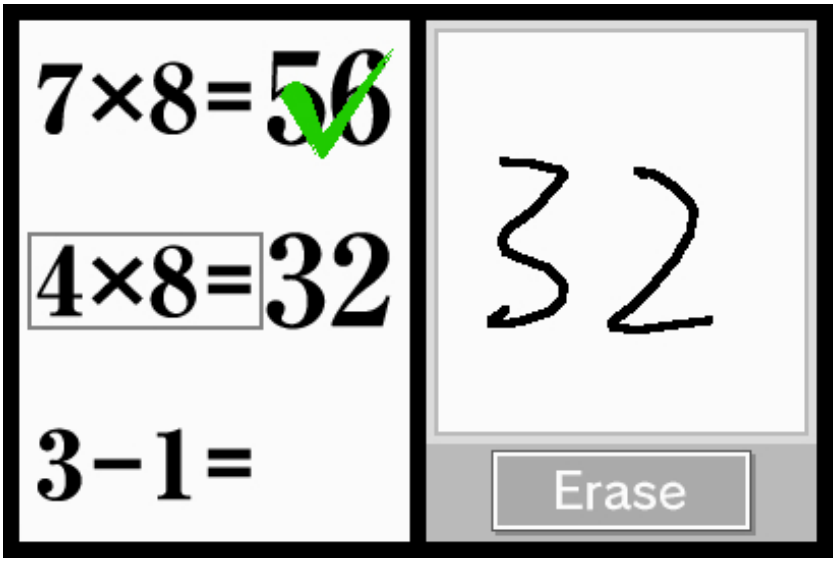


Figure 2.6: Brain Training math exercise

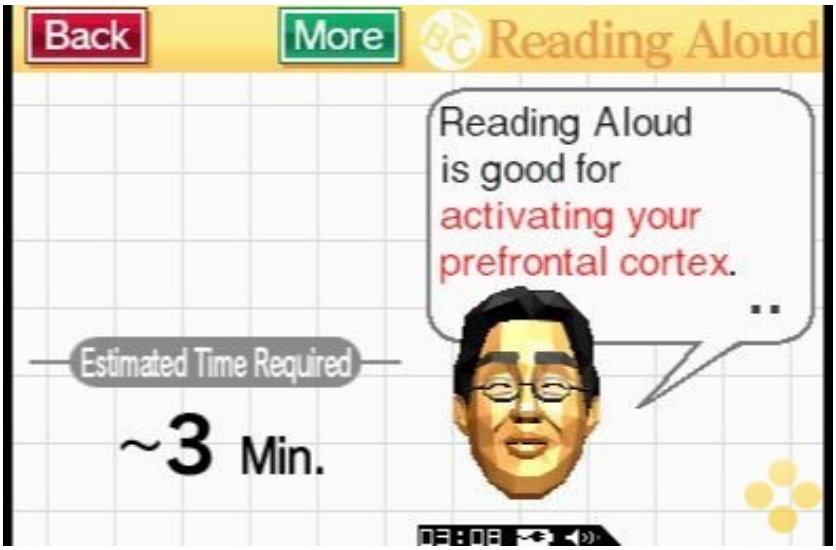


Figure 2.7: Brain Training reading exercise

### CityOne

CityOne is a game developed by IBM and offers players the opportunity to optimize banking, retail, energy and water solutions via an online, sim-style game in which the player is tasked with guiding industries within a city through a series of missions. Players will make decisions to improve

the city by attaining revenue and profit goals, increasing customers' and citizens' satisfaction, and making the environment greener with a limited budget. In parallel, players will learn how the components of business process management, service reuse, cloud and collaborative technologies make organizations in the city system more agile[15]. CityOne is a game that falls within the categories serious game and simulation.

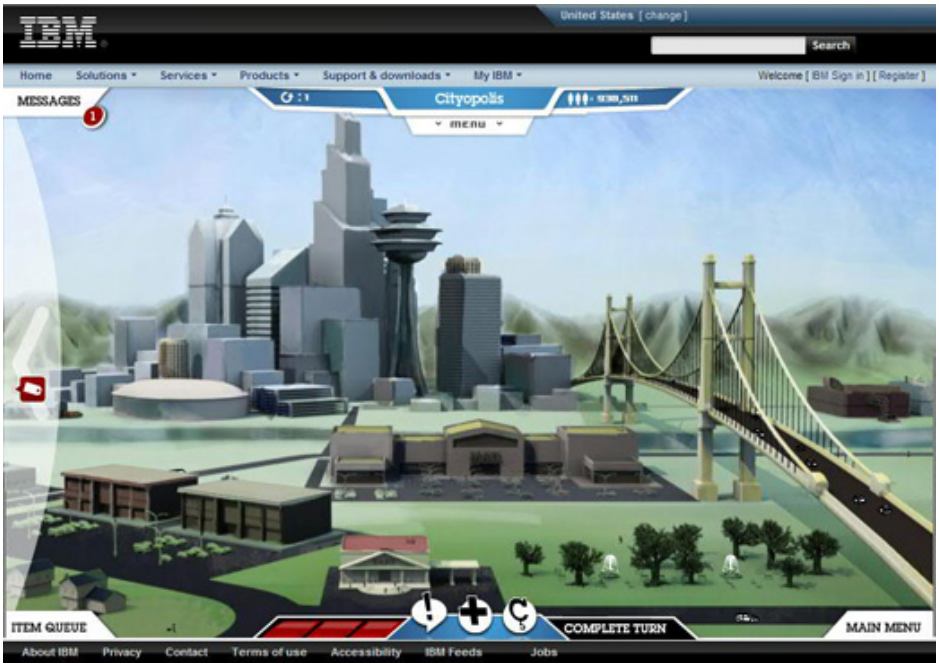


Figure 2.8: CityOne dashboard

### Plantville

Plantville is an online gaming platform developed by Siemens that simulates the experience of being a plant manager. Players are faced with the challenge of maintaining the operation of their plant while trying to improve the productivity, efficiency, sustainability and overall health of their facility[27]. The game enables players to improve the health of their plants by learning about and applying industrial and infrastructure products and solutions from Siemens. Gamers will be measured on a number of Key Performance Indicators (KPIs), including safety, on time delivery, quality, energy management and employee satisfaction[27].


Figure 2.9: Plantville, in-game

Plantville is a way for Siemens to engage customers, employees, prospects, students and the general public while driving awareness of Siemens technologies and brands[27]. We categorize Plantville as a serious game with promotional goals.

### 2.3.2 Existing solutions for research purposes

#### OxyBlood

OxyBlood is a serious game with the main goal of teaching young students about the basic functioning of a human's circulatory system. The game is a single player RTS, where the player has to create and coordinate units such as red blood cells, in order to successfully manage the circulatory system[3]. The game was developed for the web using WebGL. The WebGL library GLGE was also used[3]. An evaluation process of OxyBlood started in 2011 but the results have not been published yet (June, 2012).

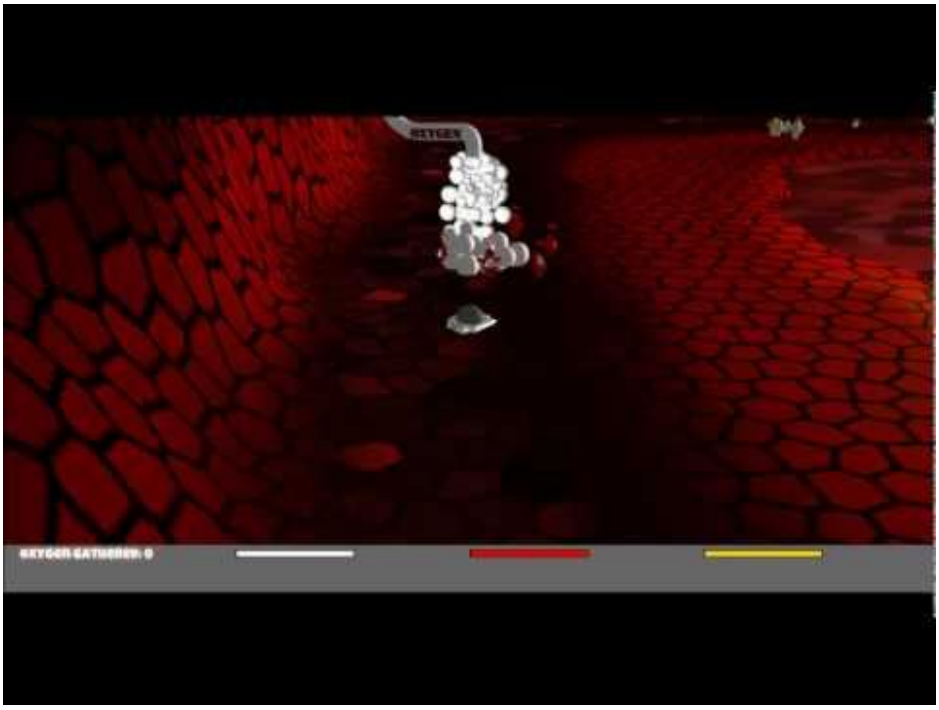

Figure 2.10: OxyBlood, in-game[3]

### SimParc

SimParc's main objective is to serve as an epistemic/educational tool. The player takes on a role and discusses, negotiates and makes decisions about environment management. The idea is to help park managers, stakeholders and all researchers involved in park management to explore and train for conflict identification, negotiation and decision strategies for management of parks, with various perspectives involved, e.g. biodiversity conservation, social inclusion and sustained development[34].

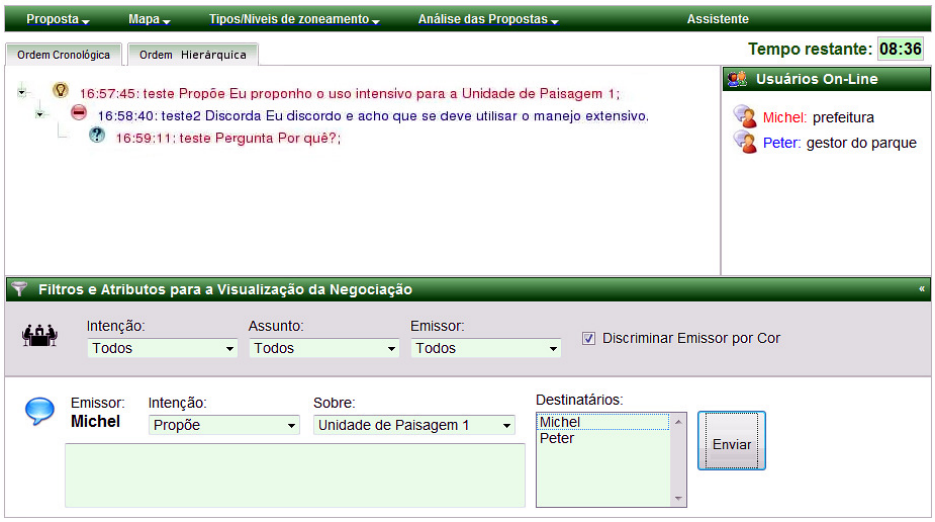


Figure 2.11: SimParc UI[34]

SimParc is based on a role-playing game[34] and incorporates a negotiation process that takes place within a park council. This council includes representatives of various stakeholders (e.g. community, tourism operator, environmentalist, nongovernmental association, water public agency). The game focuses on a discussion within the council about the "zoning" of the park, i.e. the decision about a desired level of conservation of the park[34].

An evaluation of the game showed that test participants felt the game was *"a great exercise for negotiation, with active interaction and interest of players, further encouraged by the possible exchange of role"*[34]. It was also reported that knowledge gained after playing the game was related to the territorial zoning of parks, mainly by the players that did not have prior knowledge about environmental management.

### Code Red

Code Red: Triage, is a game for learning how to classify emergency victims. The back story of the game is a bomb explosion in the subway. The goal of the game is to teach the player a triage. A primary triage is the process of prioritizing patients based on the severity of their condition, in order to treat as many as possible when resources are insufficient for everyone to be treated immediately. The player in the role as medical officer arrives first at the scene and has to perform a primary triage. The player then learns the procedure and how to apply it on different victims in different situations[36].

An evaluation of the game was conducted using pre- and post-conceptual knowledge tests. Participants scored significantly better after playing the

game[33].

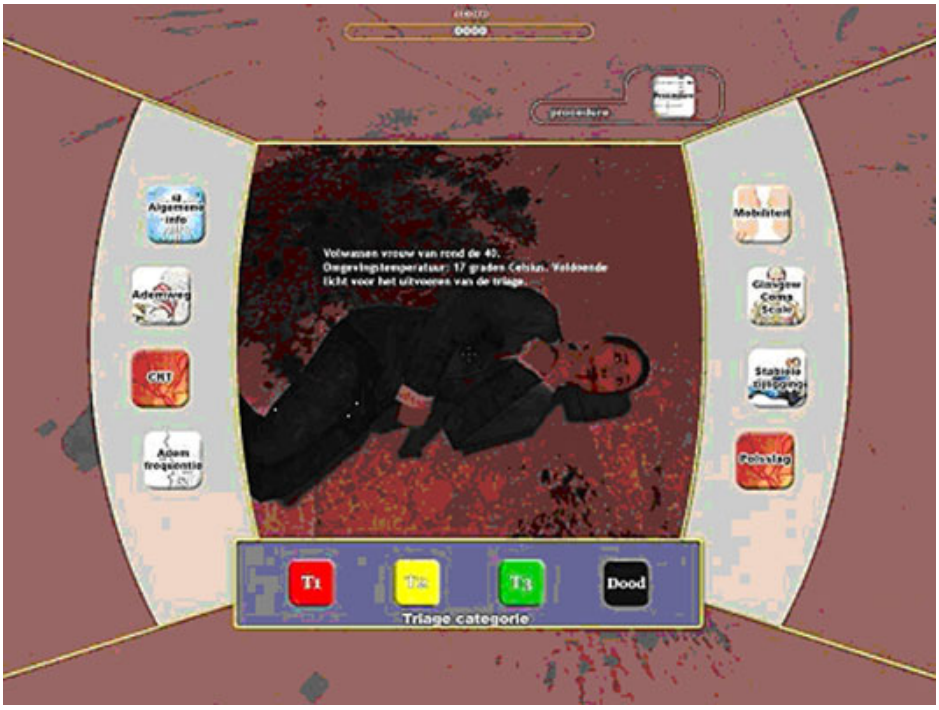


Figure 2.12: Code Red: Triage interface[36]

### Orientation Passport

Orientation Passport is a personalized orientation event application for smart phones, that applies gamification (i.e. game achievements is utilized to present orientation information in an engaging way and to encourage use of the application) to help new students at university[13].

A study showed that the application and its functions were useful for orientation at the university. The use of gamification (i.e. achievements) was well received; 96,1% of the participants agreed that *"the achievement system added value to their orientation experience and that the achievement system was fun to use"*[13].

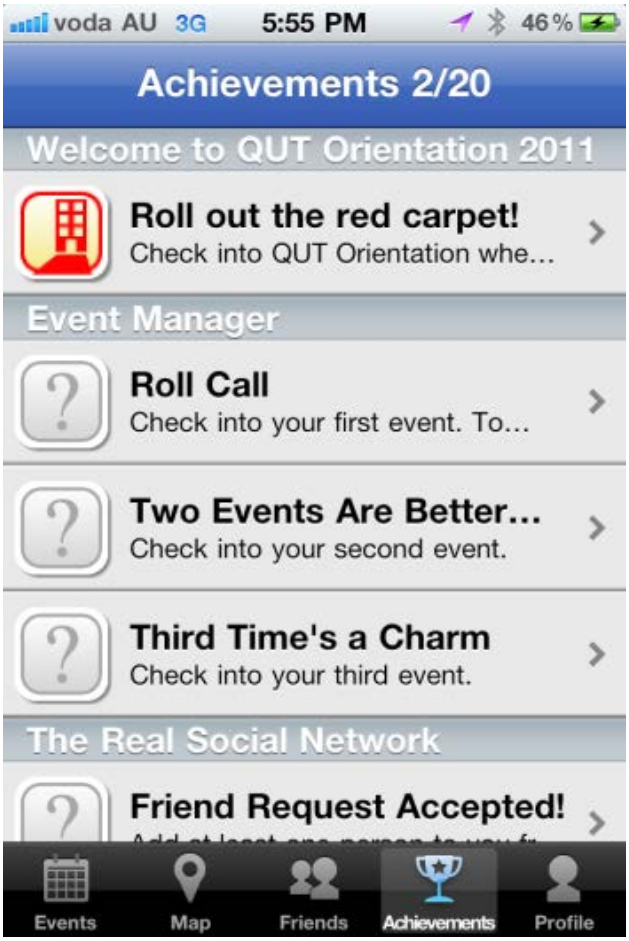


Figure 2.13: Orientation Passport[13]

## 2.4 The separation process

In addition to gaining knowledge about serious games, gamification and other related fields, it was necessary to gain knowledge about oil and gas separation.

An oil well is an underground repository that mainly consists of three different components; crude oil, gas, and water. An oil rig, or an oil production facility, is used to drain oil wells and separate the three different components (crude oil, gas, and water) from each other to produce some marketable products, i.e. oil and gas[26]. How this process is done varies in the petroleum industry but commonly a three-phase gravity separator is used to separate the components[26].

The separation process that was gamified is based on a three-phase gravity separator[26]. The separator is divided into two parts; the separator

tank and the oil tank. These two parts are separated by a vertical wall, see Figure 2.14.

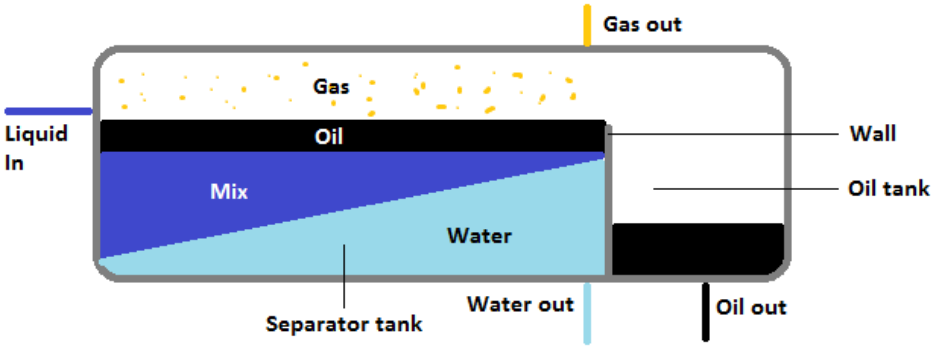


Figure 2.14: Illustration of the separator

The mixed fluid drained from the oil well first enters the separator tank. In the separator tank oil, gas, and water will separate because of gravity and form three layers[26]. The oil will separate from the water and form a layer of oil that floats on top of the water. Gas rises to the top of the tank. Figure 2.15 shows a schematic of a three-phase gravity separator and how the three different components separate. Figure 2.16 illustrates what happens when the fluid enters the separator tank.

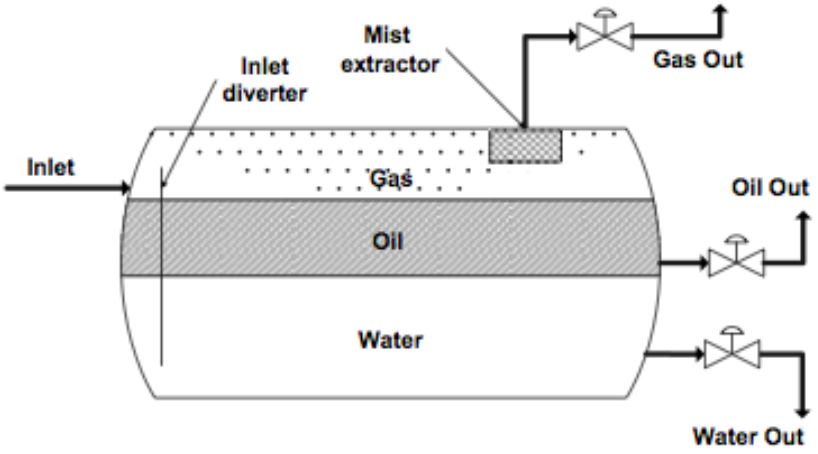


Figure 2.15: Schematic of a three-phase gravity separator[26]

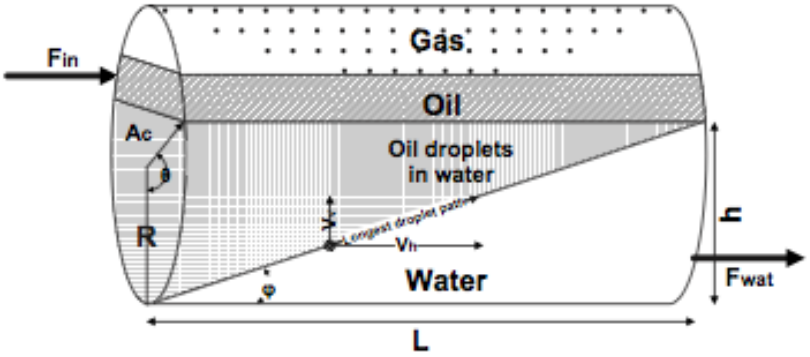


Figure 2.16: Oil separation dynamics under normal conditions[26]

Figure 2.16 shows how the fluid (i.e. oil droplets in water) behave under normal conditions. An abnormal condition would be high water outflow, which causes the oil to mix with the water, illustrated in Figure 2.17. This condition is implemented in the simulator.

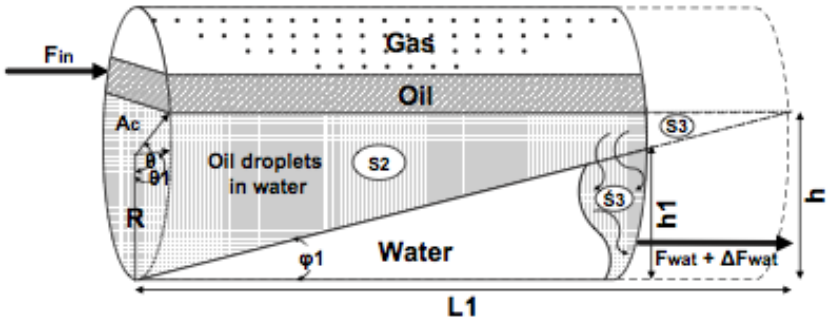


Figure 2.17: Oil mixes with water due to high water outflow[26]

The goal of the implemented separation process is for the process operator to produce as much oil and gas as possible with the highest quality possible. Oil quality is affected by how much water is in the oil, while the gas quality is affected by the pressure in the tank.

The separation process is controlled by opening or closing four different valves, see Figure 2.14. One valve (fluid in) is used to control the inlet of mixed fluid that enters the separator tank, another valve (water out) is used to drain fluid (i.e. water) from the separator tank, a third valve (oil out) is used to drain fluid (i.e. oil) from the oil tank and a fourth valve (gas out) is used to control the pressure in the tank. The latter is directly related to

the gas production. Opening or closing any of these valves will affect the pressure in the tank, which affects the total production.

The separation process explained here (and implemented in the system) is a simplification of the real-life separation process, meaning that some factors have been excluded (e.g. that the fluid can contain sand and pebbles).

### 2.4.1 Goal of separation process

We defined three goals for the process controller to strive for:

1. **High quality oil:**
   Producing high quality oil means releasing as little water as possible into the oil tank.

2. **High quality gas:**
   Producing high quality gas means that the produced gas should contain the smallest amount of oil possible. This is achieved by keeping the gas pressure below a certain value.

3. **High production:**
   High production means that as much oil and gas as possible should be produced in the given amount of time.

## 2.5 Chapter summary

Serious games are often defined as games used for purposes other than entertainment[30]. Usually these games are used for training, advertising, simulation, or education[30]. Gamification can be defined as the process of game-thinking and use of game mechanics to engage users and solve problems[37, p. xiv]. We support these definitions and we think of serious games as applications that are used in a serious context, e.g. for training or education, and gamification as game mechanics to gamify *something* for the purpose of e.g. motivation, training, or making that *something* more fun.

All of the definitions provided in Section 2.1: Definitions overlap. From the definitions it can be seen that (digital) serious games is a form of e-learning, and edutainment. It can also be concluded that (digital) game-based learning is a branch of serious games. Gamification can be related to all of these definitions. However, gamification is not necessarily the same as a game (rather the use of game mechanics) and gamification does not necessarily need to be used for training, learning, etc. Figure 2.18

illustrates how we see the relationship between these different areas.

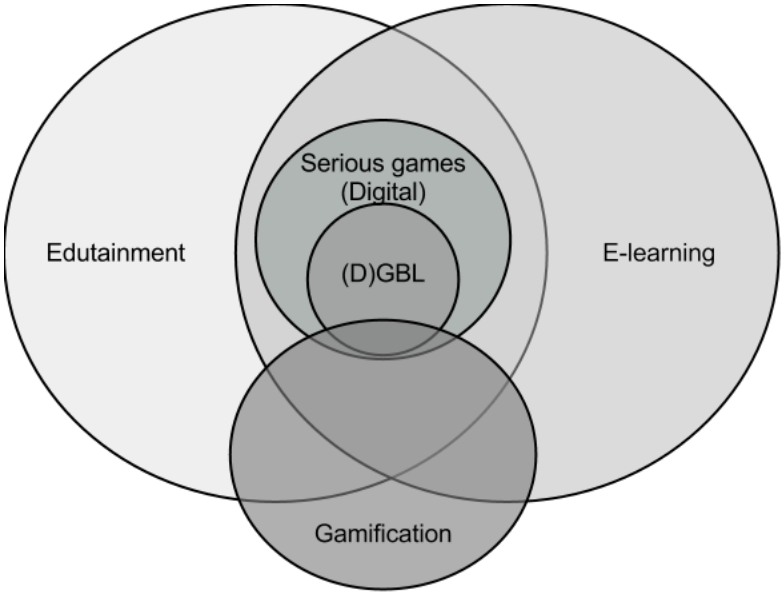


Figure 2.18: The relationship between serious games, gamification, GBL, E-learning and edutainment

A lot of research has been conducted on serious games and related topics. In general, results have shown that the use of games and game mechanics for increasing motivation, skills and understanding is effective. Though a lot of research has been done, there are still many areas that need more research. We could not find any research on the use of serious games or its related topics in process control systems or, in any similar systems.

# Chapter 3

# Game concept

Based on the background research presented in Chapter 2: Background, we designed a game concept that implements game mechanics, to answer our research questions. In this chapter we will explain this game concept and also the process of creating the game concept.

## 3.1 Creating the game concept

Before implementation of a game idea could start, it was important that we had several different game ideas to consider. This section explains the process of creating a game concept in cooperation with ABB.

### 3.1.1 First iteration

06.02.12 we had a meeting with ABB in Oslo to discuss the design process, ideas, and requirements for a game concept. After the meeting with ABB we came up with a couple of ideas for a game concept. These ideas were based on the use of gamification and restricted in both user interactivity and physical screen space, due to requirements from ABB. We presented these ideas to ABB which suggested that we should do a more thorough brainstorming and that we should eliminate any restrictions when thinking of new ideas.

### 3.1.2 Second iteration

The second iteration of the brainstorming process was done more structured than the first iteration. We first thought of game genres and games that we had played or knew about that we thought would be suitable for the separation process, see Table 3.1.

| | | |
|---|---|---|
| Runners | 2D gunners | RPG |
| Racing | Tower defence | Platformer |
| Adventure | Puzzle | Lemmings |
| RTS | Break Out | Pac Man |
| Tycoons | Beat' Em Up | Quiz |
| Slingshot | | |

Table 3.1: Game genres and games for inspiration

Using these genres and games we came up with several ideas for a game concept, some of them are listed in Table 3.2.

| | | |
|---|---|---|
| Pipes | Maze | Bricks |
| OiLemming | Platform Defence | OilTycoon |
| OilFeed | OilDig | RocketBlimp |

Table 3.2: Game concepts

Most of these ideas were eliminated using a funnel metaphor; many ideas come in, one comes out, see Figure 3.1. The elimination was based on which ideas we wanted to use and which ideas we though was fitting for the separation process.

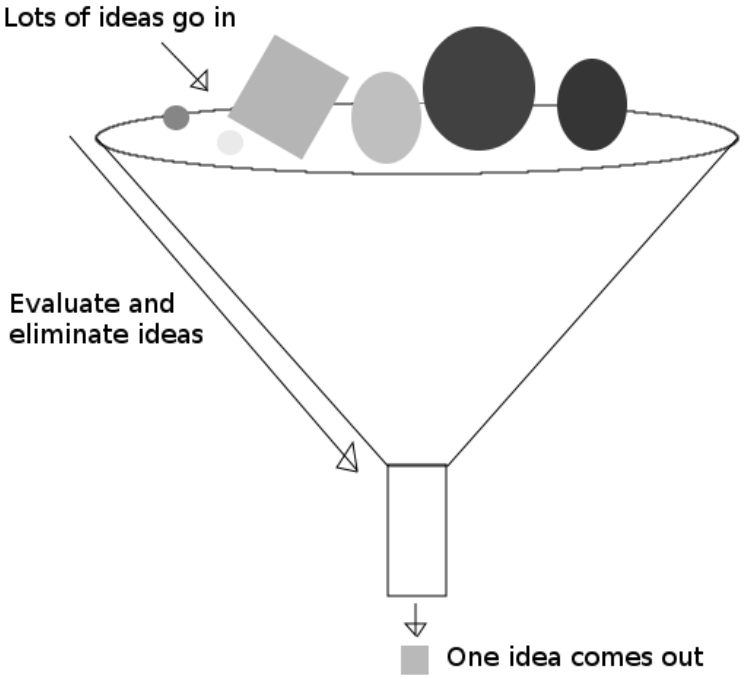


Figure 3.1: Idea funnel

Ten ideas remained after the elimination process. These ideas were presented to ABB the 24.02.2012. ABB thought that these ideas were too "out of the box". Most of the ideas required too much interaction from the user, the ideas had a poor logical connection to the domain of oil and gas separation, and they did not promote learning of the separation process in a good way. So we decided in agreement with ABB that we should do another session of brainstorming, going back to the original concept of gamification, meaning that we should incorporate game mechanics but not make a typical game.

### 3.1.3 Third iteration

After the discussion with ABB, the 24.02.12, we had a new brainstorming session. During this session we thought of game mechanics that could be used to gamify the separation process, see Table 3.3.

Based on these game mechanics we thought of three ideas that could be used to gamify the separation process.

| | | |
|---|---|---|
| Timers | Bonuses | Star/skull system |
| Score points | Experience points | Levelling |
| Element uses/actions | Reward/penalty system | Progression |
| Quests/goals | Ranks | Achievements |
| Stats | Timing | Multipliers |
| Titles | | |

Table 3.3: Game mechanics

### Goals and XP

This concept was based on the use of goals. When a goal was completed, the operator would be awarded with experience points. These experience points would be used in a ranking system or to give the process controller different statuses, e.g. "Most productive".

### Element uses and stars

The idea of this concept was based on the use of elements, e.g. you have X valve actions (open/close) to start with and you get score points based on how many you have left. The score points would be used to reward the operator with stars to represent his performance.

### Action and reward/penalty

This concept was based on the idea of rewarding or punishing the user based on his actions. The reward or penalty would affect the operator's score. Each action would be represented with a star or a skull, representing a positive or negative action.

The 27.02.2012 we had a new discussion with ABB where we presented the three new concepts which was well received. With these ideas we had a good starting point and came to agreement with ABB that the game concept should have score points, a reward/penalty system, usable elements, and a quiz (if there was time). The game concept is explained in detail in Section 3.2: Gamifying the separation process.

## 3.2 Gamifying the separation process

Games for training or education need to incorporate certain qualities for them to be effective tools for training or learning[18]. Mayo describes different effective paradigms for learning; experimental learning, inquiry-based learning, self-efficacy, goal setting, cooperation, and continuous feedback, tailored instructions and cognitive learning[18]. For more detailed information on these paradigms and other elements for learning, see Section 2.2.4: Important game mechanics for learning. In our game design we used all of these paradigms, except cooperation.

To implement these paradigms we used the ideas discussed in the game concept creation process, see Section 3.1: Creating the game concept. The starting point was a star/skull system, score points, a reward/penalty system and usable elements, but the game concept developed over time. Finally, the game concept consisted of the following elements: score points, a high score list, experience points, ranking, a reward/penalty system, a feedback system, tutorial, goals and an end-game summary. These game elements are explained in the next sections.

### 3.2.1 Score points

The operator starts with a score of 0. The operator will be rewarded with score points when he produces oil or gas. How many score points he achieves depends on the quality of the gas and oil (i.e. how much oil is in the gas, and how much water is in the oil, respectively) and how much oil and gas he is producing at the moment. The game concept also has events that affects the score (see Section 3.2.5: Reward/penalty system). For example, one event is that oil contains water. When this happens the operator gets a score point penalty which means he will lose score points.

Scoring is a form of assessment. The scoring system teaches the operator what is important within the game. A positive score indicates a good choice, a negative score a bad choice, and no score at all indicates that the actions is probably unimportant[6]. Scoring is also a form of motivation which Dantas et al. describes as one of the keys for educational success[9]. This game element is related to the self-efficacy paradigm and indirectly to the feedback paradigm (see Section 2.2.4), i.e. the operator knows if he is doing well or not by looking at the score.

### 3.2.2 High score list

A list of other operators' high scores is available to the operator at all times. The goal of the high score list is to motivate the operator to perform better.

This game element is related to the self-efficacy paradigm and the goal setting paradigm, e.g. personal goals like beating your own score, your colleagues or the top high score.

### 3.2.3 Experience points

Experience points are similar to score points, except that they only affect the operator's rank. The operator starts with 0 experience points. As the operator produces oil or gas or performs well (i.e. a positive event occurs), the operator will gain experience. When the operator has reached a certain amount of experience points he will gain a rank, which is explained in Section 3.2.4: Ranking. The experience points are also meant as a motivating factor and is related to the self-efficacy paradigm, the goal setting paradigm (e.g. personal goals like reaching the next rank) and indirectly the feedback paradigm, i.e. the operator knows that he did a good choice because he earned many experience points.

### 3.2.4 Ranking

As with the high score list, ranking is also a motivation factor. The operator starts with the lowest rank. As enough experience points are gained, the operator reaches the next rank until the last rank is reached. The ranking system is related to the self-efficacy paradigm and goal setting paradigm, e.g. reaching the highest rank.

### 3.2.5 Reward/penalty system

The reward/penalty system rewards or punishes the operator based on his actions. If the operator has a stable production of oil he will be rewarded with score points and experience points. If the operator for example transfers water over to the oil tank, he will lose score points. This game element is related to the feedback paradigm as well as to the self-efficacy paradigm.

### 3.2.6 Feedback system

The feedback system is related to the reward/penalty system and uses a star symbol to represent a positive event and a skull symbol to represent a

negative event. For each event that was created in the system, the operator gets feedback that informs him of what he did right or wrong.

According to Zichermann and Cunningham, feedback is one of the most straightforward and important game mechanics and one that is increasingly a cornerstone of the gamification movement[37, p. 77]. They define feedback as *"returning information to players and informing them of where they are at the present time, ideally against a continuum of progress"*[37, p. 77].

Michael and Chen highlights the importance of appropriate feedback regarding the assessment of serious games[6, p. 6]. They state that *"an important feature of this built-in assessment is the way the game adapts to the player's behaviour and gives the player the appropriate feedback. Players come to understand the connection between their in-game actions and the outcomes"*[6]. Similarly, Annetta et al. states that *"informed learning can only occur if both in game feedback is given and a summative, after-action review is provided for the player"*[2, p. 80].

The feedback system is related to the feedback paradigm.

### 3.2.7 Tutorial

Many game designers build learning and progression systems into their games and these are often called tutorials. A tutorial introduces the player to the basics of how to control and interact with the game. Tutorials often introduce only a few new game features or play elements at a time to avoid overwhelming the operator. By the time the player has completed these first few missions, he or she has "learned" the essentials of the game[6].

The tutorial is the only game element that is used in both the gamification version and the non-gamification version of the separation process. This is because we needed to provide the same starting basis for both test groups. Research data would not be valid and it would not be fair if some got training and some did not. The tutorial is complete when the user has produced a certain amount of oil and gas. The tutorial is related to the inquiry-based learning paradigm and the experimental learning paradigm.

### 3.2.8 Goals

The main goal of the separation process is to produce as much oil and gas as possible, with the highest quality possible, in the given time. In addition to this main goal, sub-goals were also added to the separation process. When a goal is completed the operator receives a notification and is he awarded with score points and experience points. As with many of the other game elements, the goals are meant for motivation and is related to the goal setting

paradigm and the self-efficacy paradigm. According to Prensky, goals are one of the key characteristics of a computer game and affects motivation[24, ch. 5, p. 1].

### 3.2.9 Game session summary

When the operator is done, he is presented with a summary that displays how well he did. This is done by showing the operator how well he performed, what goals he achieved and not achieved, and what feedback he received during the separation process. Having a post-action review can lead to informed learning[2, p. 80].

# Chapter 4

# Implementation

In this chapter we describe how we implemented the game concept with an existing solution from ABB. First we present the existing solution, we then present the technologies chosen for implementing the created system, then the architecture of the created system is presented and finally we present the final solution.

## 4.1 Existing solution

Our solution was integrated with an existing prototype of a process control system from ABB called HawkEye. HawkEye is similar to the "real" process control system ABB delivers, System 800xA, but provides some new features like dragging, zooming, etc. Being a prototype HawkEye has a much smaller code base than System 800xA.

HawkEye is implemented in C# using .NET and WPF. It loads graphic files called XAML files at runtime as needed. These files are displayed on a canvas in the center of the application, as seen in Figure 4.1.

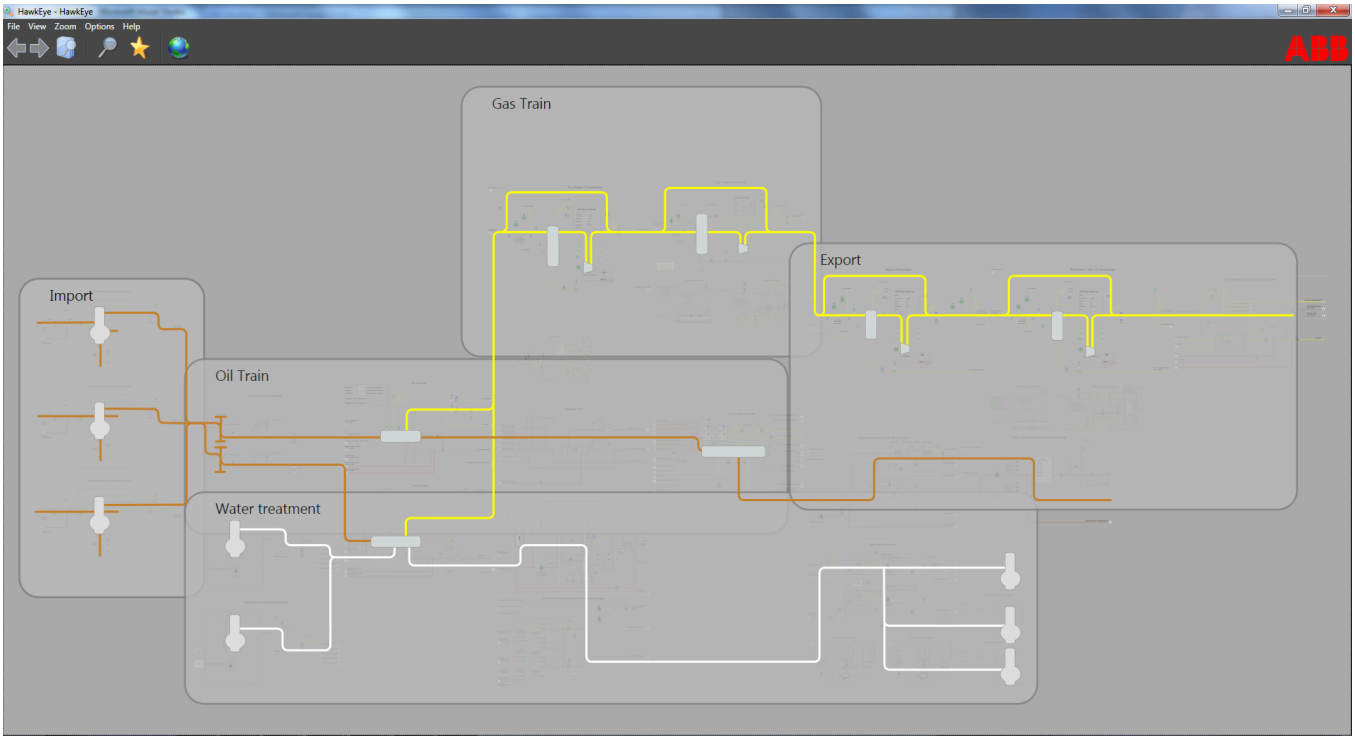


Figure 4.1: Existing solution, HawkEye

## 4.2 Chosen technologies

In this section we explain which technologies was chosen to implement the project. Since our solution was integrated with ABB's HawkEye, it was natural for us to use the same technologies used in HawkEye's implementation.

### 4.2.1 .NET

The .NET Framework is an integral Windows component that supports building and running applications and Web services[21].

There are a lot of different programming languages that can use the .NET platform, we chose C# because we had prior experience with that programming language. When a .NET project is compiled high level code (C# code) is compiled to IL-code. The CLR (Common Language Runtime) then decides how to make the IL-code executable[14, p. 5].

### 4.2.2 WPF

WPF (Windows Presentation Foundation) is a graphical display system for Windows. It is designed for .NET, and is influenced by modern technologies like HTML and Flash[17, p. 1]. WPF employs XAML, which define the arrangement of panels, buttons and controls that make up the windows in a WPF application[17, p. 1].

### 4.2.3 WPF Toolkit

WPF Toolkit[7] is a WPF library. It includes, amongst other classes, a Chart class. The Chart class was used to visualize the operator's performance using graph charts.

### 4.2.4 MS SQLServer

MS SQLServer Express[22], is a SQL server from Microsoft, and was used for logging user performance and high sore.

## 4.3 Architecture

When the game concept explained in Chapter 3: Game concept, was complete, an architecture for the system was created, see Figure 4.2.

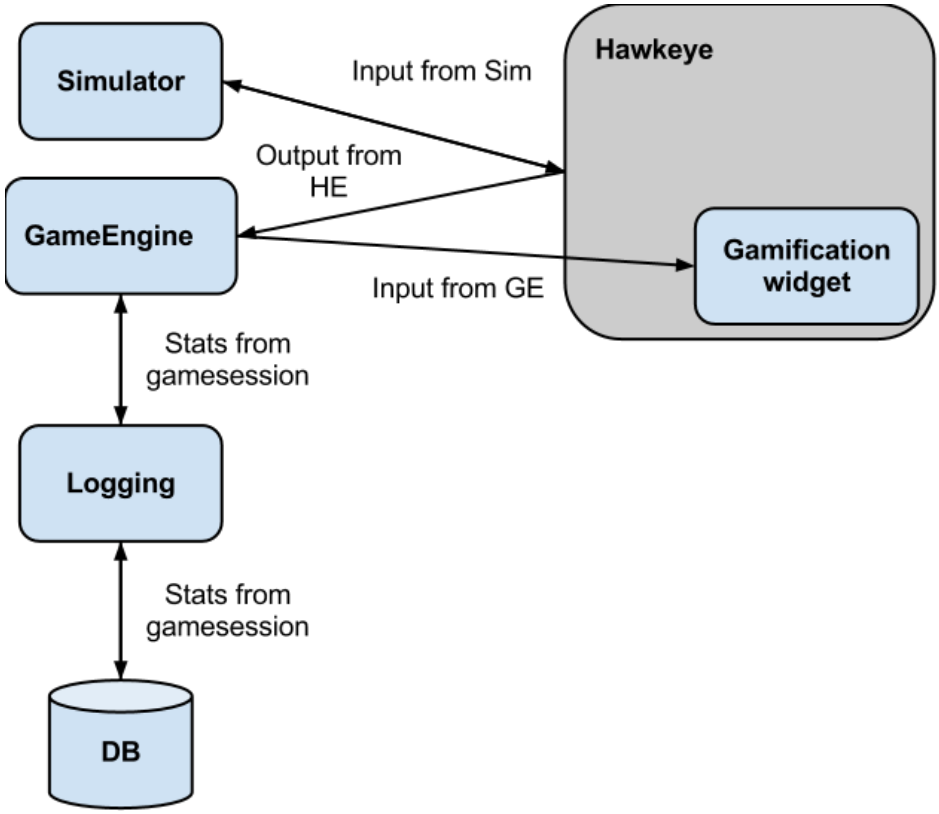


Figure 4.2: Architecture for the implemented solution

The system is divided into two main components; a gamification widget which is the gamification aspect of the system, and a simulator that simulates the oil and gas separation process. Additionally, the architecture includes a logging mechanism that communicates with a database to log the simulator's state each second, and a game engine that is responsible for updating the gamification widget.

## 4.4 Our solution

Our solution implements a simulator of the separation process, a visual representation of the separation process, a gamification widget (and other game mechanics) and a logging mechanism.

### 4.4.1 Implementation of the simulator

To implement the simulator, a mathematical model for how oil and gas separates from water was needed. A paper by A. Sayda and J. Taylor[26] was

acquired and found accurate enough for this use. Some simplifications had to be done on how to model gas behaviour. These simplifications made the way gas behaved in the simulator less intuitive (to the user) than we wanted.

The simulator was implemented with two chambers, one where the liquid enters to separate (separator tank) and another one where the oil can be let out (oil tank), see Figure 4.3.

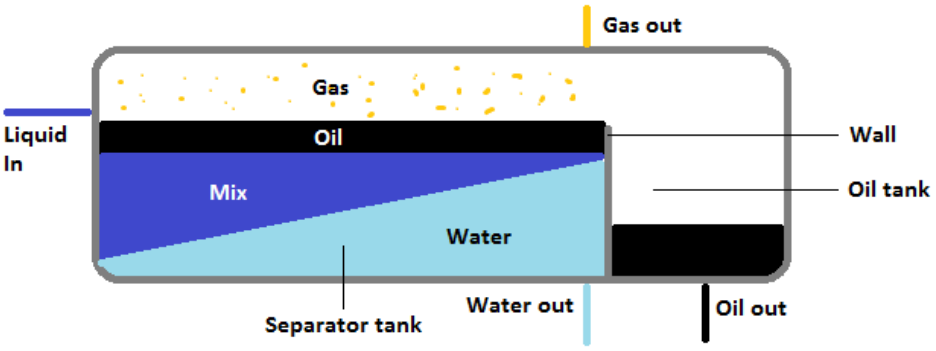


Figure 4.3: Explanation of the separator

The simulator monitors four valves (Liquid In, Gas out, Oil out and Water out, from Figure 4.3) and then calculates the liquid flow (i.e. how much liquid that enters and leaves both tanks), the level of liquid in both tanks and the gas pressure. See Figure 4.4 for a simplified version of how the simulator works, for more information on the calculations see [26].

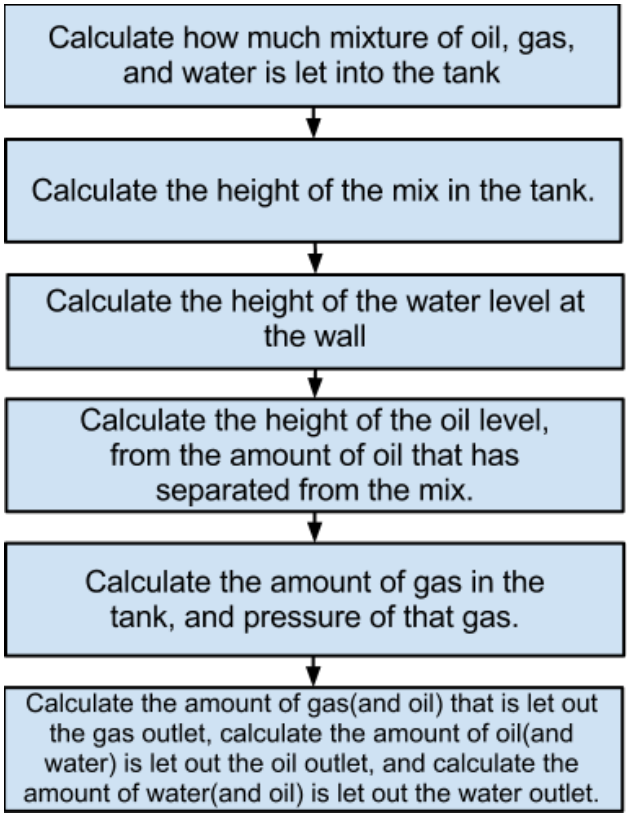


Figure 4.4: Simulator operations per time unit

### 4.4.2 Visual representation of the separation process

In order to represent the separation process, an XAML file was created, see Figure 4.5 for an overview of the final solution. This XAML file included four different graphical elements; paths which represents pipes, valves that the operator can open from 0% to 100%, text that represents the quality of the oil, gas and water and a graphical representation of the separator.

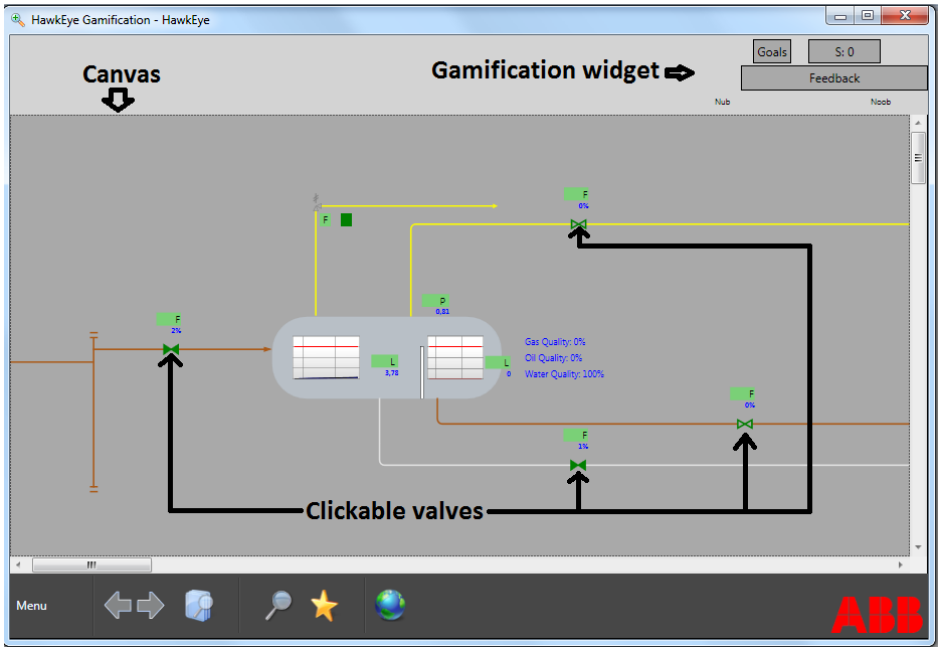


Figure 4.5: HawkEye with the gamification widget

### Valves

When a valve is clicked, the operator is presented with a slider which he can use to adjust the opening of that valve, see Figure 4.6. The valves were implemented as a graphical element with a value for how much the valve was opened. These values were used to do calculations in the simulator and they were stored in the database using the logging mechanism, see Section 4.4.5.

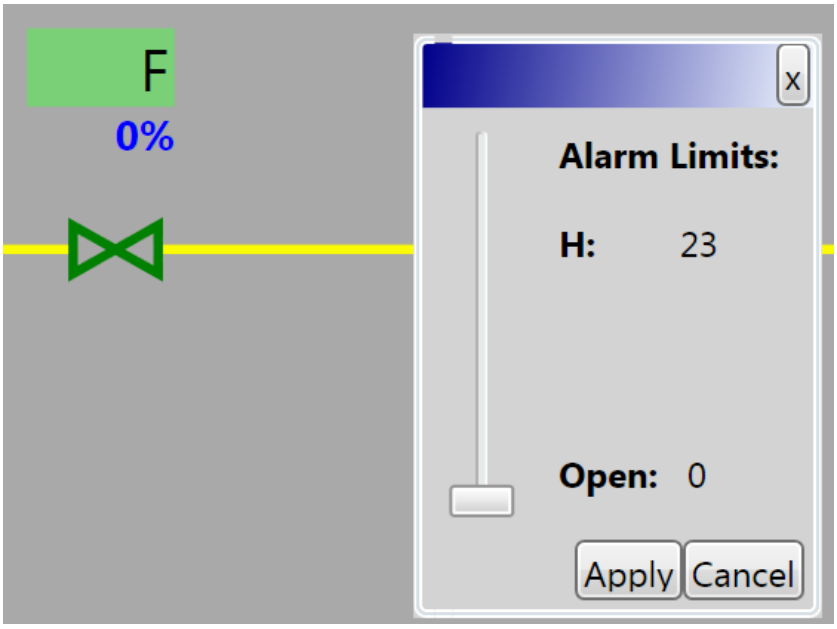


Figure 4.6: Valve slider

### Separator

To visualize the separation process, two different graphical separators were implemented. The separator was initially represented as seen in Figure 4.7.

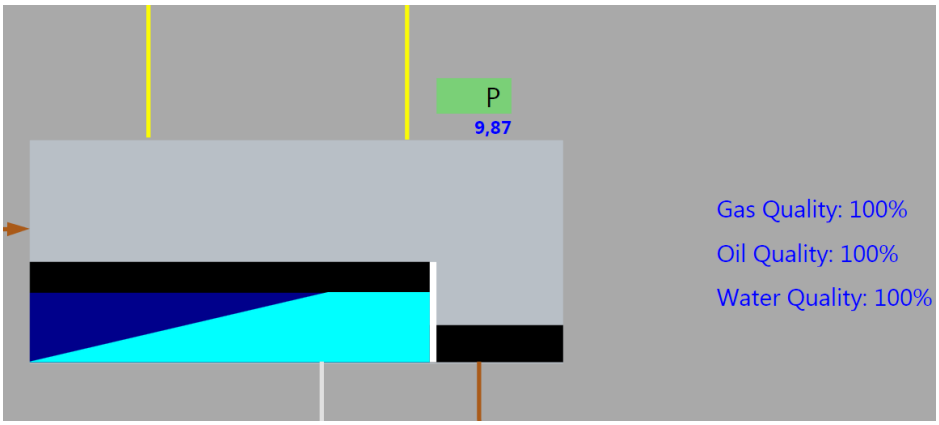


Figure 4.7: Initial graphical representation of the separator

In Figure 4.7, the light blue area is the area of separated water, the dark blue area is the mixture of oil and water, and the black area is the layer of

oil. When the height of the oil layer is greater than the height of the wall, oil flows into the oil tank.

After discussing the representation of the separator with ABB, we decided to represent the separator in a way that more closely resembles the way separators are represented in the existing system ABB delivers. The final representation of the separator can be seen in Figure 4.8.

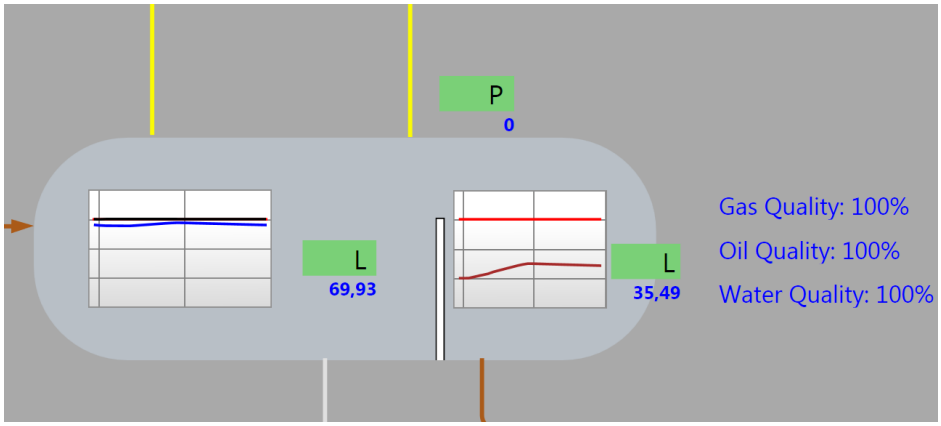


Figure 4.8: Final graphical representation of the separator

The chart on the left represents the first chamber of the separator (the separator tank). The dark blue line in the chart represents the water level over time, when it reaches the red line water flows into the oil tank. The black line indicates the oil level over time, it is desirable that the black line lies on top of the red line, this means that oil is flowing into the oil tank. The chart on the right represents the second chamber of the separator (the oil tank). The brown line in the graph indicates the liquid level in the oil tank.

### 4.4.3 Gamification widget

The gamification widget is implemented as a subclass of the WPF class UserControl. This means that it can be dragged and dropped as a graphical element when designing GUI applications using VisualStudio and WPF. In addition to the widget, a GameEngine class is implemented. The game engine is responsible for updating the gamification widget at given intervals and when feedback is given or a goal is completed.

The widget implements four main game mechanics; score points, goals, feedback, and experience bar. In addition, the widget has three clickable

items; the score button, the feedback button, and the goals button. When something important happens in the widget, like the user receiving feedback, the whole widget pulsates in addition to the related button (e.g. the feedback button). The gamification widget is presented in Figure 4.9.

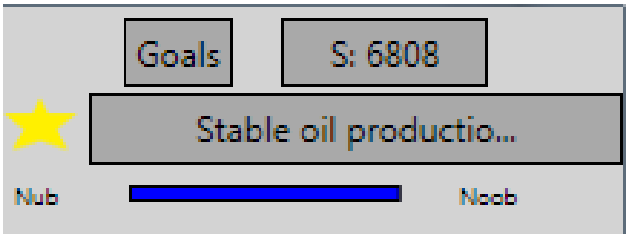


Figure 4.9: The gamification widget

### Score points

Score points is one of the main game mechanics that was implemented. The operator gains score points according to his production and the quality of oil and gas. When the operator clicks the score button, he is presented with a high score list and an overview of the oil production, see Figure 4.10.

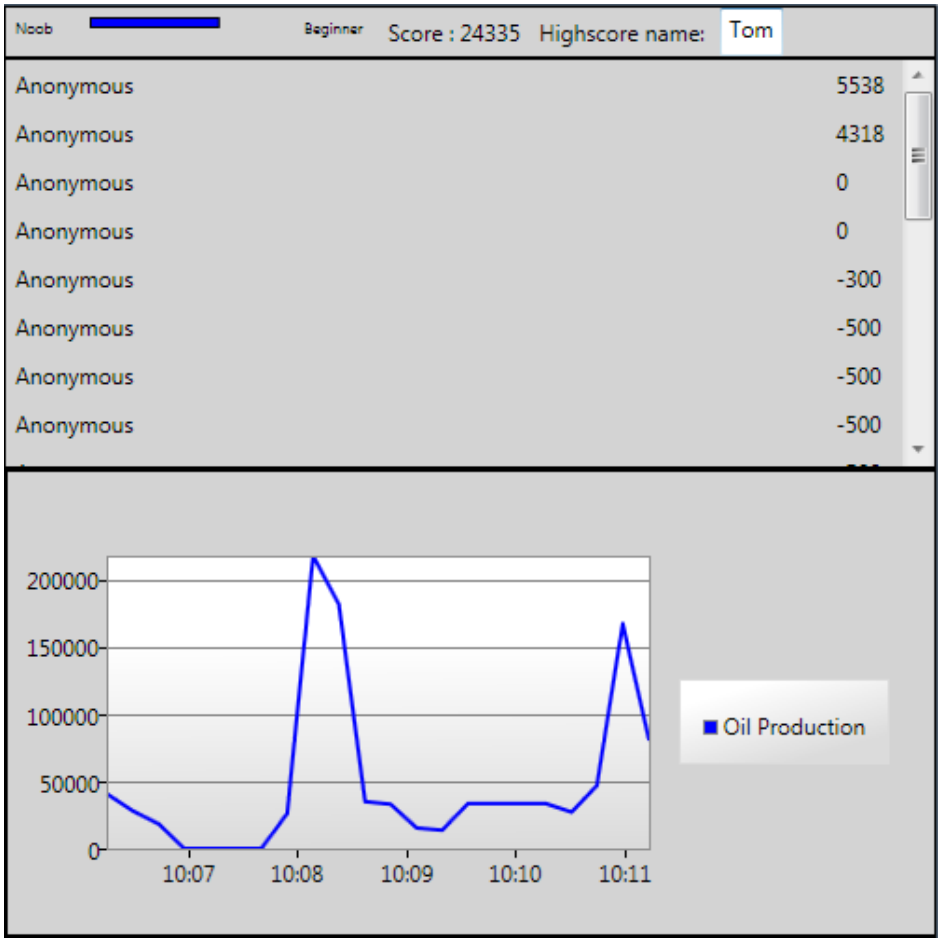


Figure 4.10: The high score list and overview of oil production

### Goals

Another game mechanic that was implemented is goals. Goals were implemented as an XML file with defined conditions for completion, in addition to score points and experience points. When the operator completes a goal, the goal button pulsates in a blue colour. When the operator clicks the goals button, he is given an overview of completed goals and goals he has yet to achieve, see Figure 4.11.

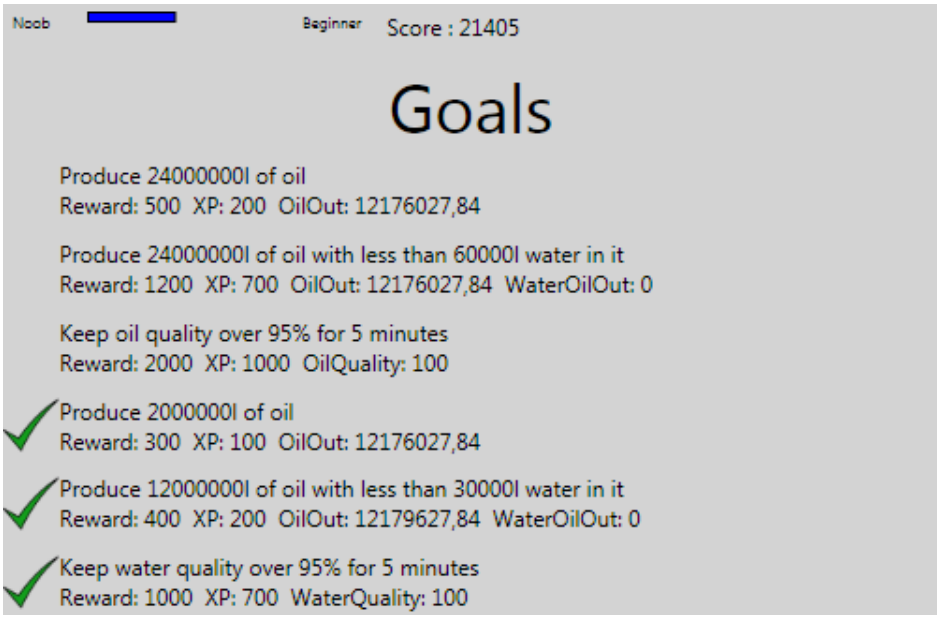


Figure 4.11: An overview of completed and non-completed goals

### Feedback

Feedback is also an important game mechanic in the widget. Feedback is given to the operator when he triggers a positive or negative event, e.g. when oil contains water. When the operator is given feedback, the feedback button pulsates in a blue colour and displays that feedback directly in the button (as well as in a tooltip when hovering the feedback button), see Figure 4.9. When the operator clicks the button, he is presented with an overview of the feedback he has received during the separation process, as seen in Figure 4.12.

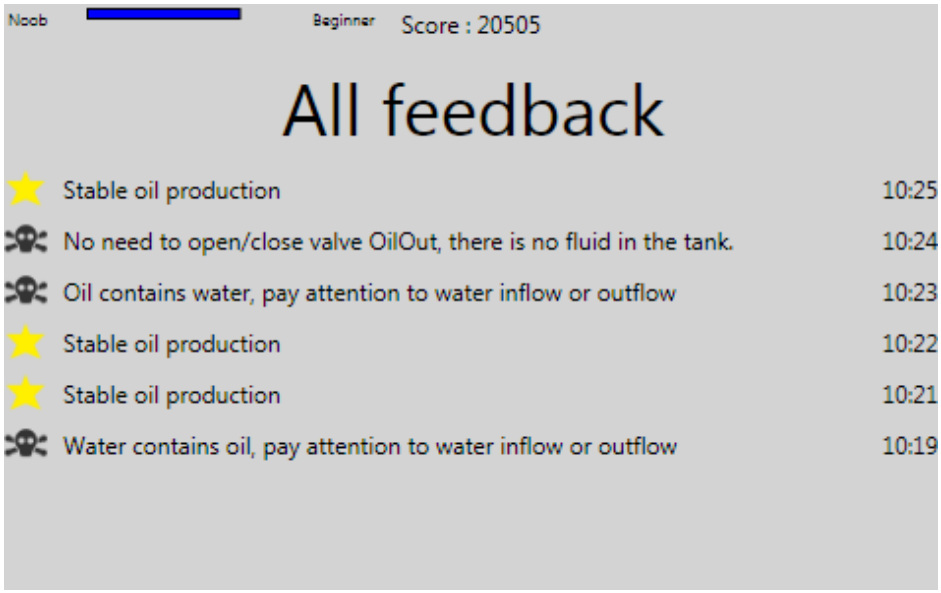


Figure 4.12: Overview of received feedback

As can be seen from Figure 4.10, Figure 4.11 and Figure 4.12, the operator's current score and experience progression is available at all time.

### Experience bar

The experience bar represents the rank of the operator and the progression towards the operator's next rank, see Figure 4.13. Ranks are implemented using XML. The XML file specifies how many experience points are needed to progress from one rank to another, in addition to the next rank's name and description (which can be seen when hovering the rank name). Experience points are awarded for producing oil or gas in addition to completing goals. The game engine is responsible for updating the experience bar.


Figure 4.13: Experience bar

### 4.4.4 Other game mechanics

This section introduces other game mechanics that was implemented that are not related to the gamification widget.

#### Tutorial

A tutorial was created to give users training before trying out the separation process and the application. The tutorial consists of text boxes that pops up at critical moments in the separation process. The tutorial is finished when a user has produced a certain amount of oil and gas. See Figure 4.14 for an idea of how the tutorial works.

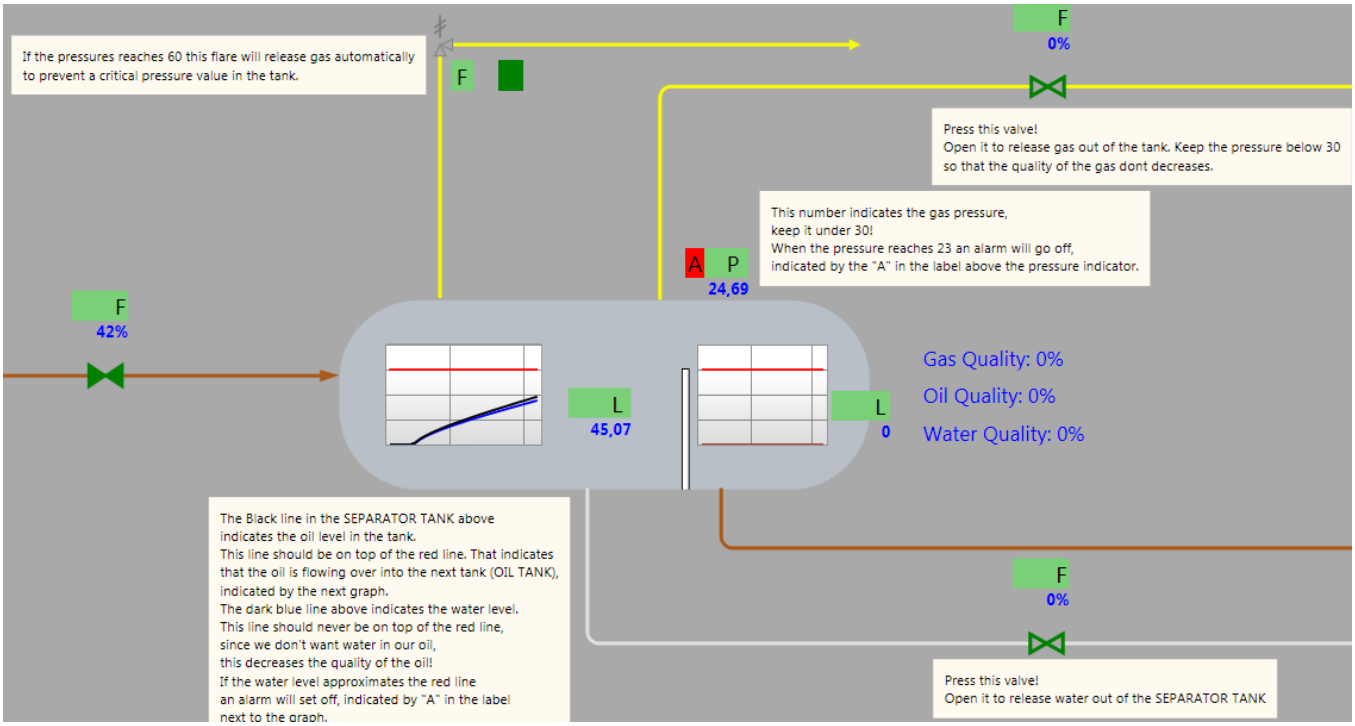


Figure 4.14: Tutorial

When an action is considered completed, the corresponding text box is removed, see Figure 4.15 for an example of this. The image on the left shows a hint from the tutorial, the image on the right shows that it is hidden when the hint is considered unnecessary.

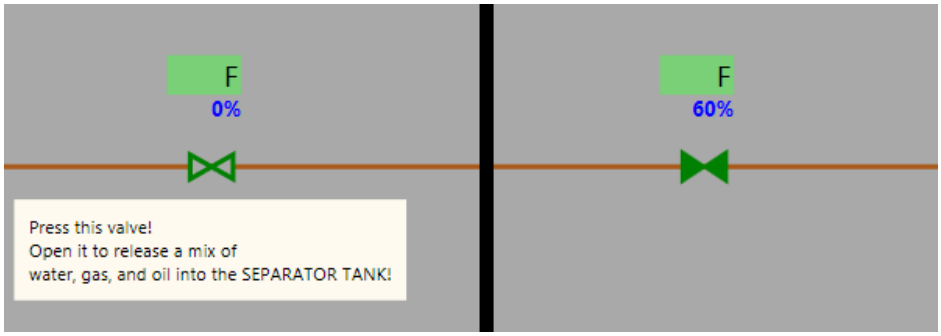


Figure 4.15: The tutorial adapts to the situation

### The summary

When the gamified separation process is ended the operator is presented with a summary screen. The summary can also be seen as a game mechanic and is important for learning[2, p. 80]. The summary shows the operator's performance using charts and stars, completed (and not completed) goals and the feedback received during the separation process, see Figure 4.16.

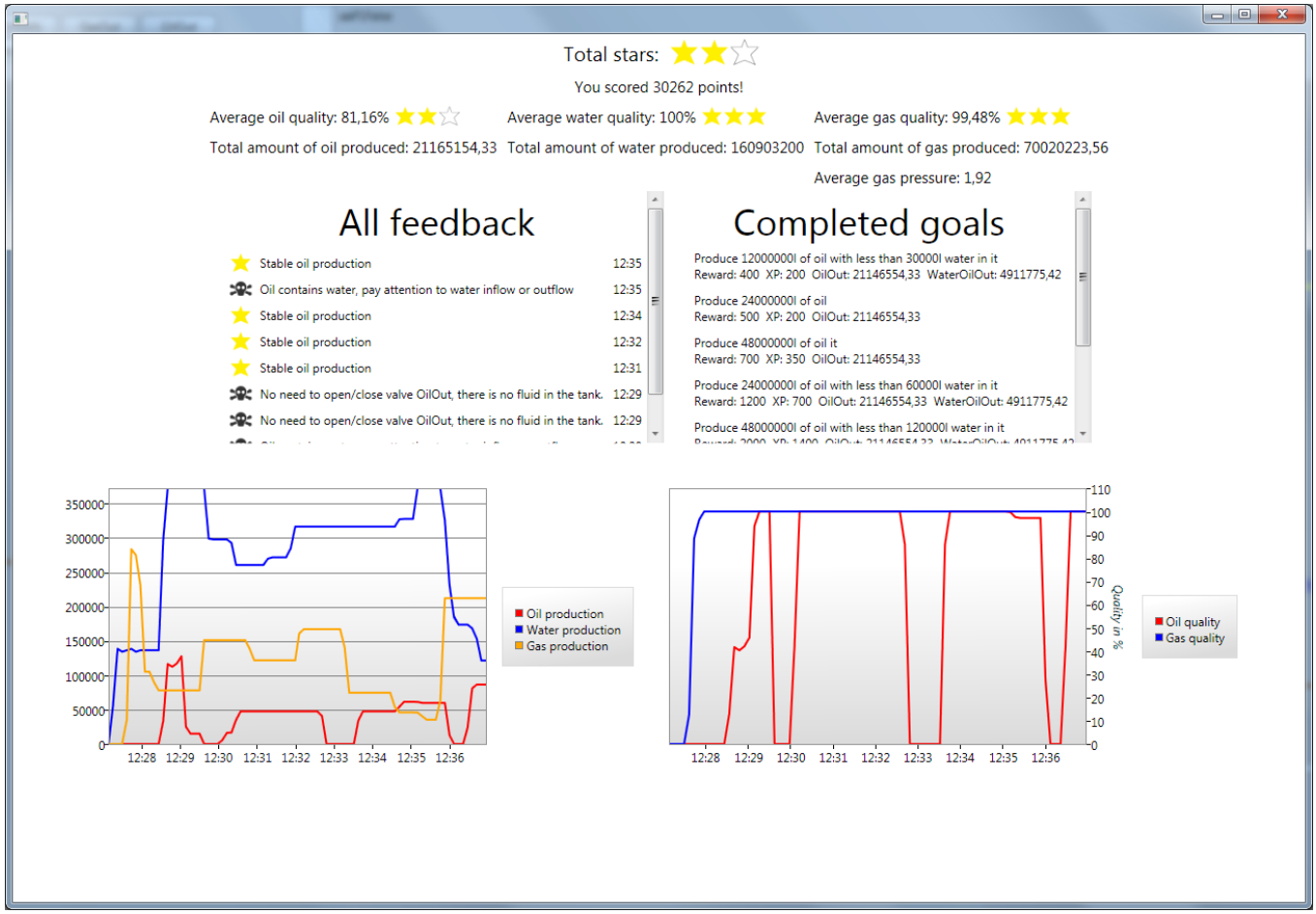


Figure 4.16: The summary

### 4.4.5 Data logging

To support analysis of the operator's performance, a database was created to keep track of each operator's actions and the simulator's state each second (i.e. the total amount of oil produced, oil quality, gas pressure, etc.). The logging system is not a game mechanic, but it is a tool for in-depth analysis of the operator's performance.

# Chapter 5

# Research questions and method

This chapter introduces our research questions, the research method used and the design of the research experiment.

## 5.1 Research questions

In a process control system, the user interface has to be minimalistic and informative. This means that the process operator cannot be distracted by non-critical information and that critical information must be easily accessible to the operator. With these constraints in mind, we defined three research questions to determine whether a gamified oil and gas separation process in a process control system is beneficial for the operator.

**RQ1:** *Can a gamified separation process improve an operator's motivation?*

Does gamification motivate an operator to do a better effort in his job, and is the separation process more fun to perform with gamification?

**RQ2:** *Can an operator's skills be improved by gamification?*

Can gamification help the operator to do a better job, i.e. produce as much oil and gas as possible with the highest quality possible?

**RQ3:** *Can gamification improve an operator's understanding of a given subject?*

Will gamification help the operator to gain a better understanding of the task domain, i.e. will the operator get a better understanding of the separation process?

## 5.2 Research Method

There is a lot of on going research in the field of software engineering. Technologies, methods, tools, etc., are continuously being improved. Unlike other disciplines however, there has been little research in the development of models of different components of the discipline. The modelling research that does exist has focused on the software product itself[4]. *"We need research that helps establish a scientific and engineering basis for software engineering"*[4]. Victor R. Basili discusses various experimental methods to meet this requirement; the scientific method, the engineering method, the empirical method, and the mathematical method[4].

1. **The scientific method:**
   In the area of software engineering this paradigm might be used when trying to understand the software process, product, people, and environment. The method tries to extract a model from the world which tries to explain the underlying phenomena, and evaluate whether the model is representative of the phenomenon being studied. An example of this method can be an attempt to understand how software is being created to look for solutions to execute the process in a more efficient way.

   This method requires you to observe the world, propose a model or a theory of behaviour, measure and analyse, validate hypotheses of the model or theory, and if possible repeat the procedure.

   Basili lists the engineering method and the empirical method as variations of the scientific method:

   1.1. **The engineering method:**
   This version of the paradigm is an evolutionary improvement oriented approach which assumes one already has models of the software process, product, people and environment and modifies the model or aspects of the model in order to improve the thing being studied. An example might be to study improvements to methods being used in the development of software, or to demonstrate that a certain tool is better than its predecessor, relative to some

criteria. An important part of this method is the need for analysis and measurement.

This method requires you to observe existing solutions, develop, measure and analyse, and repeat the process until no more improvements appear possible.

1.2. **The empirical method:**
This version of the paradigm begins by proposing a new model, not necessarily based upon an existing model, and attempts to study the effects of the process or product suggested by the new model. An example can be the proposal of a new method or tool used to develop software in new ways. As with the engineering method, analysis and measurement is important to prove that the new method or tool is a step up from an existing solution.

This method requires you to propose a model, develop statistical/qualitative methods, apply to case studies, measure and analyse, and validate the model and repeat the procedure.

2. **The mathematical method:**
This is a deductive analytical model which does not require an experimental design, but provides an analytic framework for developing models and understanding their boundaries based upon manipulation of the model itself.

This method requires you to propose a formal theory or a set of axioms, develop a theory, derive results and if possible compare with empirical observations.

The empirical method was used to conduct the research. We looked into existing solutions in the field of serious games, GBL, gamification and e-learning. A prototype application was developed and we conducted an experiment to analyse the effects of the implemented game mechanics.

## 5.3 Research design

To answer our research questions an empirical study was conducted. The study used a triangulated research method that consisted of a user test, a quiz, a survey and an interview, to gather both qualitative and quantitative data. The experiment was divided into three phases; pre-test, test, and post-test, see Figure 5.1. During the pre-test a verbal explanation of the separation process was given, before the participant got to operate the separation process in form of a tutorial. In the test phase the participant

carried out the separation process followed by a quiz. After the quiz the participant would do the separation process one more time. When the two test sessions were completed, the participant would, in the post-test, answer a survey and afterwards an interview would take place. Each test lasted about 50 minutes. The research was conducted with N = 20 participants (most of them students), divided into two groups consisting of ten participants each. One group, group RF, was the control group. The other group, group GF, was the experimental group. The following sections will explain the techniques used in the research method.

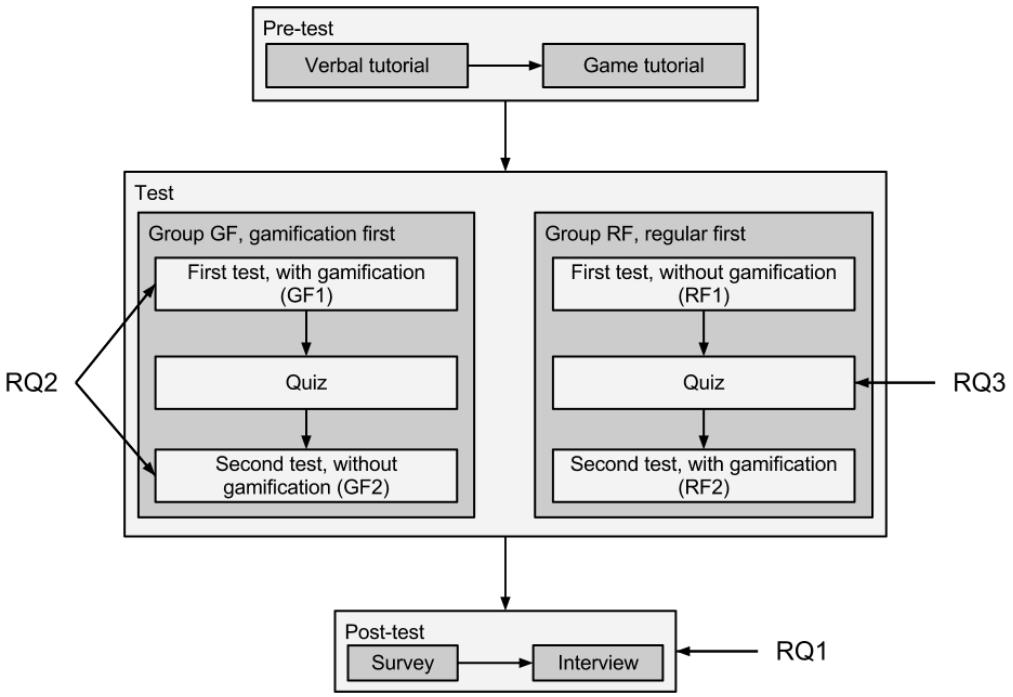


Figure 5.1: Experiment flow

### 5.3.1 User test

A usability test normally simulates a real situation and is used to evaluate the usability of a system. The user (the tester) is observed while he solves specific problems. The goal of a usability test is to gain the insight needed to improve the system that is being tested[31, p. 20]. The goal of the user test was not to test the usability of the created solution, but to determine whether a gamified separation process could increase the praticipants' motivation, skill and understanding.

Each group tested the application with and without gamification. What separated the two groups were in which order the participants would execute the separation process, that is, whether they executed the separation process with gamification first or without gamification first. Each participant in group GF conducted the test with gamification first and then without gamification. Each participant in group RF conducted the test without gamification first and then with gamification. Figure 5.1 illustrates this way of conducting the experiment. For each participant the two tests in the test phase lasted for 10 minutes each.

The system log's the simulator's state (i.e. oil production, oil quality, gas production, gas quality, gas pressure, etc.) every second (and when a valve is opened or closed). If a valve was opened or closed, the valve's start and stop state would also be stored. This data was used to compare the results from the first test run of group GF (the experimental group) to the results from the first test run of group RF (the control group). How the participants improved (or not improved) from the first test run to the second test run was also compared, Figure 5.2 illustrates this.

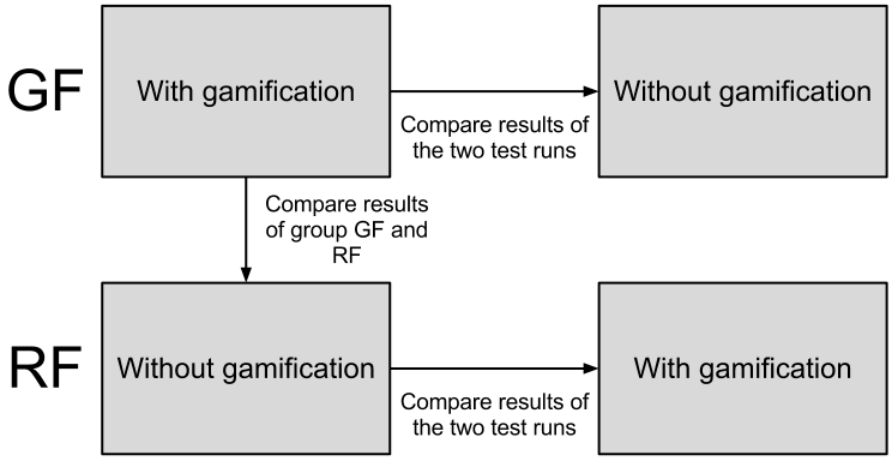


Figure 5.2: How test results were compared

Data from the user tests was used to answer RQ2, see Figure 5.1. Since we had a small sample of participants (10 in each group) and since we did not know the standard deviation, we decided to use Student's t-distribution with a confidence interval of 95% to analyse the data from the application.

### 5.3.2 Quiz

A quiz (that took the participants about 5 minutes to answer) with multiple choice questions was used to determine whether group GF had learned more about the separation process than group RF. The intentions with the quiz was to use the results to answer RQ3. The quiz can be found in Appendix D.

### 5.3.3 Survey

The survey employed a Likert scale to answer questions related to gameplay, the user interface, comparison between gamification and non-gamification, and system usability. It took each participant about 10 minutes to complete the survey. The results from the survey were mainly used to answer RQ1, but there were some questions in the survey that was related to RQ2. Questions asked in the survey can be found in Appendix B, results from the survey can be found in Appendix C.

### 5.3.4 Interview

Interviews were conducted to extract the participants' thoughts about gamification, e.g. was it helpful, was it fun, thoughts on the GUI, etc. Additionally, data from the interviews were used to explain the results of RQ1, RQ2 and RQ3. The interviews lasted about 15 minutes for each participant. The interviews allowed more descriptive answers than the survey and also allowed follow-up questions. Questions from the interview can be found in Appendix E.

# Chapter 6

# Results

In this chapter we will present the results found from the conducted experiment. The results are divided into four sections; 6.1: Results from test runs, 6.2: Results from the quiz, 6.3: Results from the survey and 6.4: Results from the interviews.

## 6.1 Results from test runs

Data was collected from the test runs to see how the participants performed. Amongst other data, it was collected how much oil, gas and water the participants produced and also the quality of their production. The results of this data is presented in this section.

The participants were divided into two groups. One group tested the application with gamification enabled to begin with, we have named this group Gamification First or GF. The other group tested the application with gamification disabled in the first test run, we have named this group Regular First or RF. As described in Section 5.3: Research design, each participant got to carry out the separation process twice, we will refer to GF run one as GF1, and GF run two as GF2. Likewise RF was divided into RF1 and RF2, Figure 6.1 illustrates this.

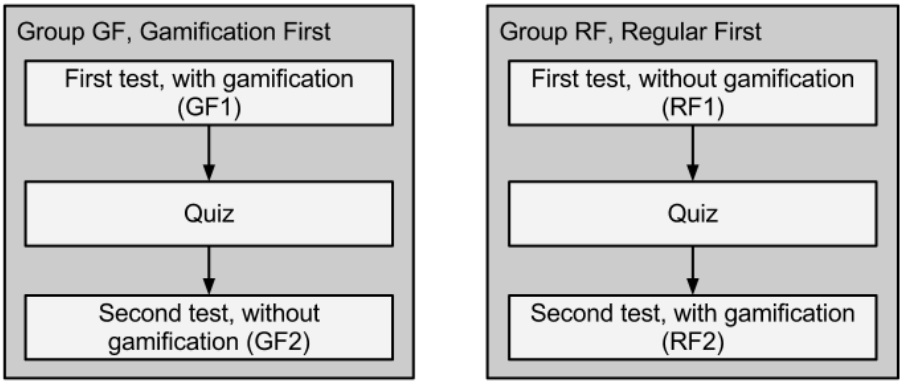


Figure 6.1: The groups GF and RF

### 6.1.1 Comparison between GF1 and RF1

| | **GF1 Mean** | **RF1 Mean** | **RF1 M.-GF1 M.** | **GF1 CI** | **RF1 CI** |
|---|---|---|---|---|---|
| Oil Prod, *(L)* | 125662,18 | 145520,03 | 19857,84 | 33071,99 | 31026,77 |
| Water Prod, *(L)* | 1071961,33 | 1176268,09 | 104306,76 | 314925,24 | 253942,48 |
| Water in oil, *(L)* | 67045,19 | 69010,15 | 1964,96 | 57800,21 | 75450,64 |
| Oil in water, *(L)* | 13,87 | 220,31 | 206,44 | 28,49 | 498,38 |
| Gas Prod, *(L)* | 464141,05 | 518634,89 | 54493,84 | 124578,06 | 96181,79 |
| Oil in gas, *(L)* | 6583,20 | 9991,31 | 3408,11 | 8173,58 | 7845,06 |
| Oil quality, *(%)* | 70,29 | 78,33 | 8,05 | 18,05 | 17,36 |
| Gas quality, *(%)* | 98,60 | 98,25 | -0,35 | 1,40 | 1,28 |

Table 6.1: Averages, differences of averages, and confidence intervals (CI) of GF1 and RF1

Table 6.1 contains the average oil production, water production, how much water that was in the oil, oil quality, how much oil that was in the water, gas production and how much oil that was in the gas, for both GF1 and RF1. The table also contains the difference between the averages of the two, i.e. the GF1 Mean subtracted from the RF1 Mean, as well as the confidence intervals of the two groups. Figure 6.2 compares the production of oil, gas and water (in litres) and the quality of oil and gas (in percentage) between the two groups. The confidence intervals for each value are also

presented.

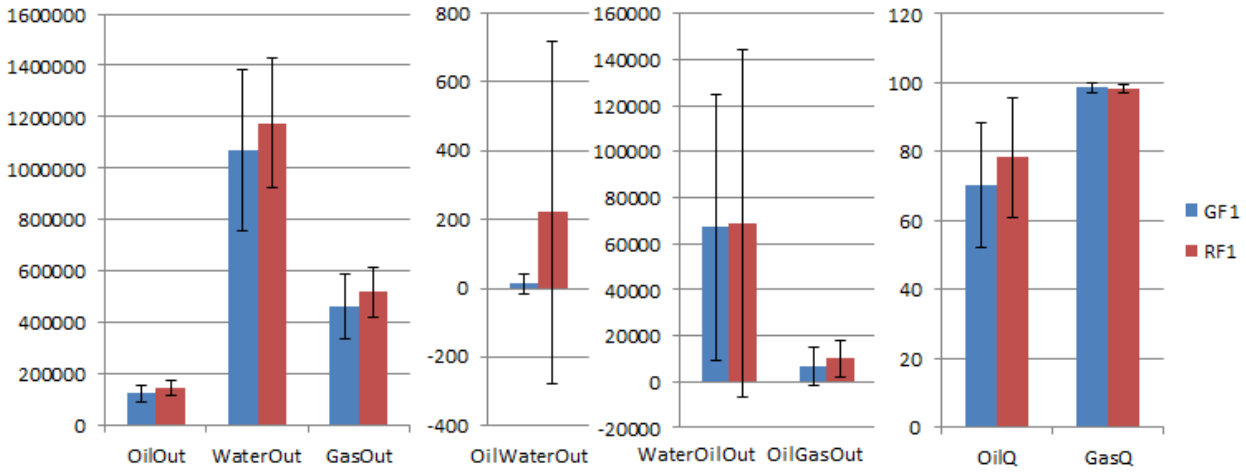


Figure 6.2: Graph representing the data from Table 6.1, with confidence intervals

From Figure 6.2 it can be seen that RF1, on average, produced more oil (OilOut) than GF1. The figure also shows that RF1 had slightly more water in the oil (WaterOilOut) than GF1, but that RF1 still had a better oil quality (OilQ). This is because of the ratio of water released in the oil and the amount of oil produced (for RF1).

It can also be seen that RF1 achieved a higher gas production (GasOut) than GF1. The gas quality (GasQ) is almost the same between RF1 and GF1, although RF1 released more oil in their gas (OilGasOut).

We were surprised to discover that RF1 performed better than GF1, but Figure 6.2 shows that none of the results can be said to be statistically significant with a confidence interval of 95%.

### 6.1.2 Comparison between GF1 and GF2

| | GF1 Mean | GF2 Mean | GF2 M.-GF1 M. | GF1 CI | GF2 CI |
|---|---|---|---|---|---|
| Oil Prod., *(L)* | 125662,18 | 135018,33 | 9356,15 | 33071,99 | 34963,28 |
| Water Prod., *(L)* | 1071961,33 | 1206536,79 | 134575,46 | 314925,24 | 322078,29 |
| Water in oil, *(L)* | 67045,19 | 13608,38 | -53436,81 | 57800,21 | 13099,81 |
| Oil in water, *(L)* | 13,87 | 94,41 | 80,54 | 28,49 | 146,74 |
| Gas Prod., *(L)* | 464141,05 | 508276,05 | 44135,00 | 124578,06 | 126339,34 |
| Oil in gas, *(L)* | 6583,21 | 7844,19 | 1260,98 | 8173,58 | 11078,46 |
| Oil quality, *(%)* | 70,29 | 89,82 | 19,53 | 18,05 | 9,20 |
| Gas quality, *(%)* | 98,60 | 98,04 | -0,56 | 1,40 | 2,91 |

Table 6.2: Averages, differences of averages, and confidence intervals (CI) of GF1 and GF2

Table 6.2 shows the differences in production and quality between GF1 and GF2. This data is represented graphically with confidence intervals in Figure 6.3.

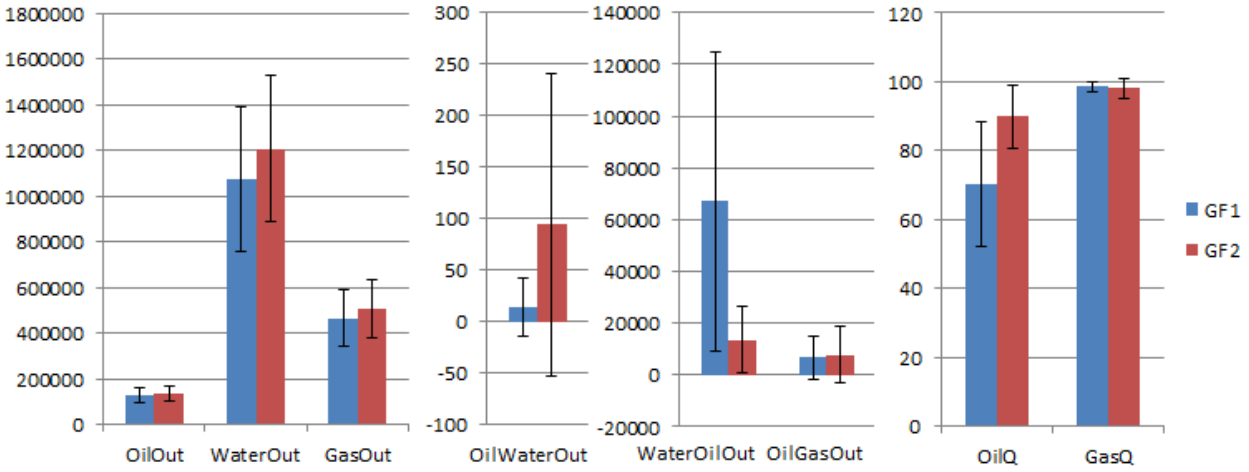


Figure 6.3: Graph representing the data from Table 6.2, with confidence intervals

From Figure 6.3 it can be seen that GF2, on average, produced more oil

than GF1, but that GF2 released more oil into the water. The figure also shows that GF2 had less water in the oil than GF1. This, and the fact that GF2 produced more oil leads to a better oil quality for GF2.

GF2 also achieved a higher gas production than GF1, but had a lower gas quality.

As with the results from the previous section, the results cannot be said to be statistically significant, as seen from the figure.

From the presented data it can be concluded that participants in group GF on average performed better in their second run, but the results are not statistically significant. Whether the improvements are because of the experience from the first run or because of gamification is unknown.

### 6.1.3 Comparison between RF1 and RF2

| | **RF1 Mean** | **RF2 Mean** | **RF2 M.-RF1 M.** | **RF1 CI** | **RF2 CI** |
|---|---|---|---|---|---|
| Oil Prod, *(L)* | 145520,03 | 142327,83 | -3192,20 | 31026,77 | 28573,99 |
| Water Prod, *(L)* | 1176268,09 | 1265583,48 | 89315,39 | 253942,48 | 203624,09 |
| Water in oil, *(L)* | 69010,15 | 20358,91 | -48651,25 | 75450,64 | 32967,62 |
| Oil in water, *(L)* | 220,31 | 58,52 | -161,79 | 498,38 | 130,86 |
| Gas Prod, *(L)* | 518634,89 | 16528,95 | 1652895,40 | 96181,79 | 82986,12 |
| Oil in gas, *(L)* | 9991,31 | 7630,47 | -2360,85 | 7845,06 | 6728,99 |
| Oil quality, *(%)* | 78,33 | 91,09 | 12,75 | 17,36 | 9,77 |
| Gas quality, *(%)* | 98,25 | 98,56 | 0,31 | 1,28 | 1,46 |

Table 6.3: Averages, differences of averages, and confidence intervals (CI) of RF1 and RF2

Table 6.3 compares the results of RF1 to the results of RF2. Figure 6.4 presents the results graphically with confidence intervals of 95%.

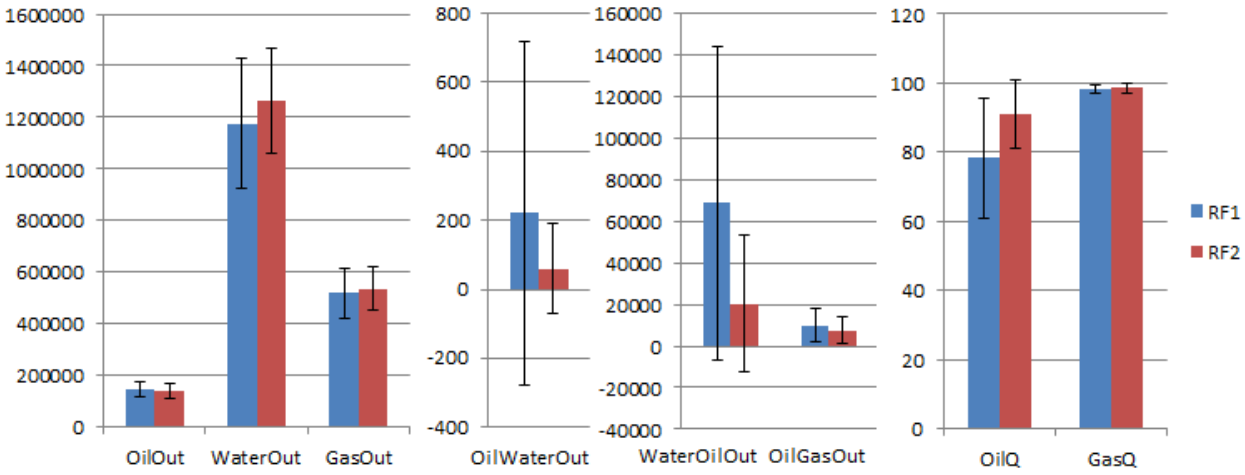


Figure 6.4: Graph representing the data from Table 6.3, with confidence intervals

From Figure 6.4 it can be seen that RF2, on average, produced less oil than RF1. This is probably because RF1 produced close to what was possible to produce within the time limits of the test. What is interesting is that RF2 produced more water, which indicates that RF2 let more fluid into the tank, but released less oil. The figure also shows that RF2 had less water in the oil than RF1 and that RF2 has achieved a better oil quality than RF1. It can also be seen that RF2 released less oil into the water than RF1.

RF2 gained a higher level of gas production than RF1 and a better gas quality. The figure also shows that RF2 released less oil into the gas, on average, than RF1.

From the presented data, it can be concluded that participants in group RF performed better in their second run. None of the improvements, however, can be said to be statistically significant with a confidence interval of 95%, as seen from the confidence intervals in Figure 6.4. Whether the improvements are because of the experience gained from the first run or because of gamification is unknown.

## 6.2 Results from the quiz

Between the two test runs, each participant answered a multiple choice quiz. The quiz asked questions related to the separation process. The questions asked were based on information given in the tutorial (which both groups completed before their first run) and on information that could be extracted from the user interface. More information could be drawn from the gamified

separation process. The purpose of this quiz was for the results to serve as data in order to answer RQ3: *"Can gamification improve an operator's understanding of a given subject?"*.

The quiz asked a total of 9 questions and each participant could score a total of 9 points. The result for each participant in both of the groups is shown in Table 6.4.

| | **Gamification first** | **Regular first** |
|---|---|---|
| Subject 1: | 7 | 8 |
| Subject 2: | 8 | 5 |
| Subject 3: | 7 | 7 |
| Subject 4: | 6 | 4 |
| Subject 5: | 5 | 6 |
| Subject 6: | 9 | 8 |
| Subject 7: | 9 | 9 |
| Subject 8: | 5 | 6 |
| Subject 9: | 6 | 7 |
| Subject 10: | 7 | 8 |
| Average: | 6,90 | 6,80 |
| Standard deviation: | 1,45 | 1,55 |
| Variance: | 2,10 | 2,40 |
| Confidence interval (t-dist): | 1,04 | 1,11 |

Table 6.4: Quiz scores

The results show that group GF got a slightly higher score than group RF. The difference between the two groups, however, is too small to conclude that gamification had a positive effect on understanding the separation process. Figure 6.5 shows that there is no statistically significant difference between the two groups.

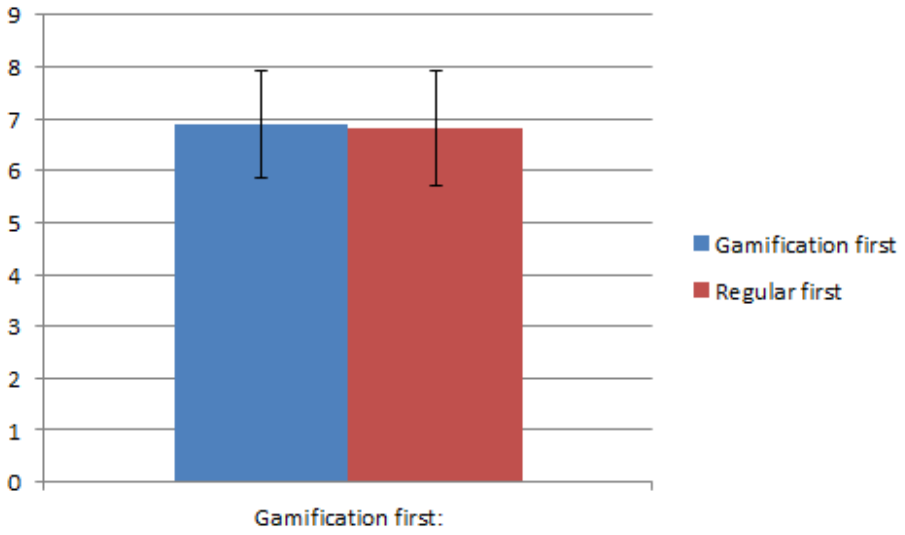


Figure 6.5: Results from the quiz

## 6.3 Results from the survey

In the post-test phase each participant replied to a survey, see Figure 5.1. The main purpose of this survey was to retrieve subjective data and to answer RQ1: *"Can a gamified separation process improve an operator's motivation?"*. In this section we will present the results we believe are the most interesting and important. The results are presented in four different sections, each section representing one of the sections from the survey.

### 6.3.1 User Interface

One of the challenges of gamifying the separation process was that gamification had to be subtle. The separation process itself has the highest priority when it comes to attention due to the damage that can be done if something goes wrong during the separation process (in a real life situation). With this in mind, we wanted to determine what the participants thought of the user interface.

One of the questions we asked (in the form of a statement) was *"I noticed when I received feedback"*. 65% agreed to this statement, 5% were neutral, while 30% disagreed. The results are shown in Figure 6.6.

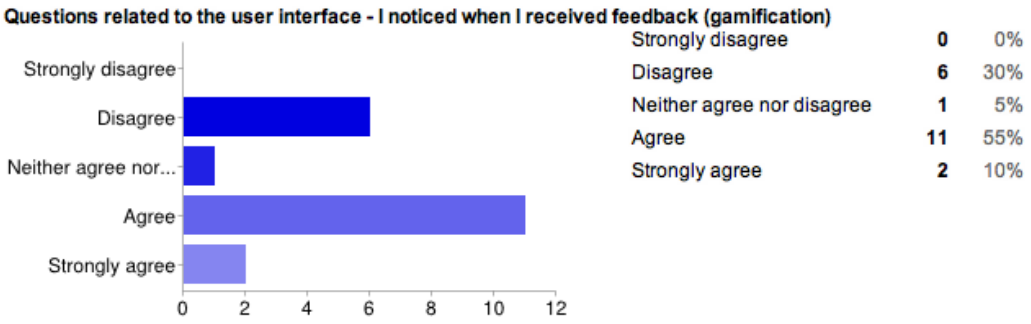


Figure 6.6: How many users noticed the received feedback

During the interview each participant was asked if he/she felt that the gamification widget was distracting or intrusive and almost everyone answered that they would like the widget to have a higher presence and be *more* intrusive.

In addition to the feedback, the system used alarms to notify the user of a dangerous situation. These alarms were not gamified elements and they were used in both test runs (i.e. with and without gamification). What is interesting is that 85% (a difference of 20%) of the participants noticed when they received an alarm compared to when they received feedback, see Figure 6.7.

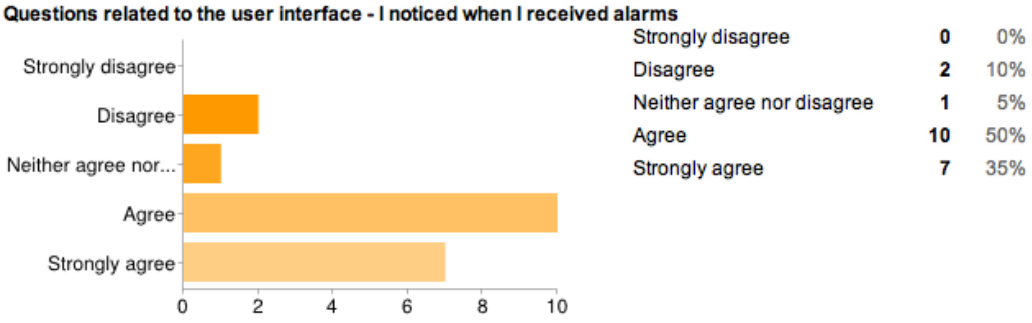


Figure 6.7: How many users noticed the received alarms

We also wanted to know if the participants spent much time looking at and interacting with the gamification widget. 30% agreed to the statement *"I spent a lot of time looking at the widget"*, 15% had a neutral opinion while 55% disagreed to this statement. The complete results are shown in Figure 6.8.

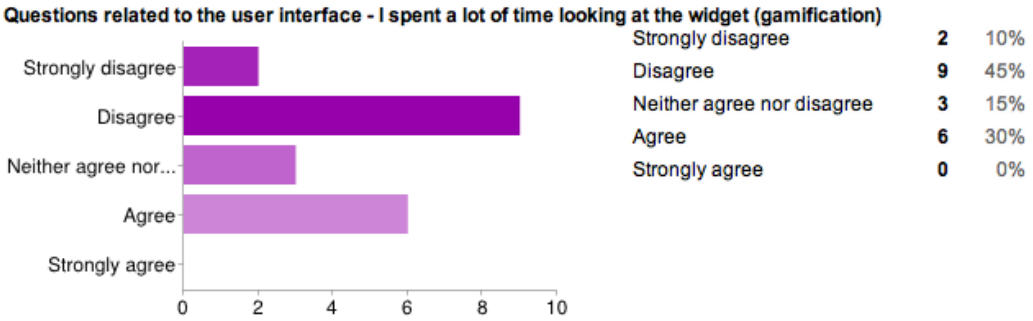


Figure 6.8: Results on whether users spent a lot of time looking at the gamification widget

Even fewer participants interacted with the widget during the test run. 70% disagreed with the statement *"I spent a lot of time interacting with the widget"*. The complete results are shown in Figure 6.9.

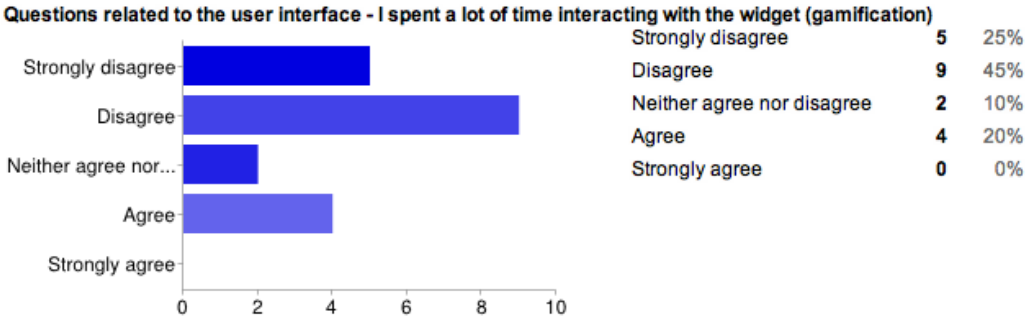


Figure 6.9: Results on users' interaction with the gamification widget

Related to the question of whether participants noticed when they received feedback, we wanted to know if they noticed when they completed a goal. As with the feedback, this information is indicated in the gamification widget. 30% agreed to the statement *"I noticed when I achieved a goal"*, 30% were neutral and 40% disagreed. The results are shown in Figure 6.10.

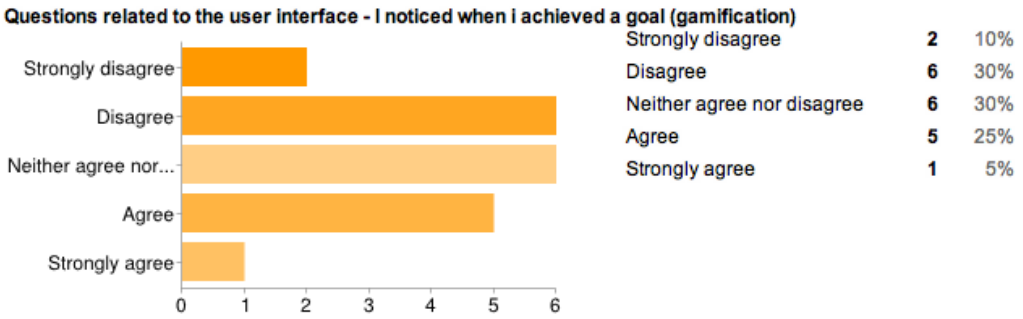


Figure 6.10: Results on whether users noticed achieved goals

In addition to the visuals of the user interface, we wanted to know what the participants thought of the controls, i.e. how easy it was to control the valves. 20% thought that the valves were difficult to control, 25% were neutral, while 55% thought that the valves were easy to control. The complete results are shown in Figure 6.11.

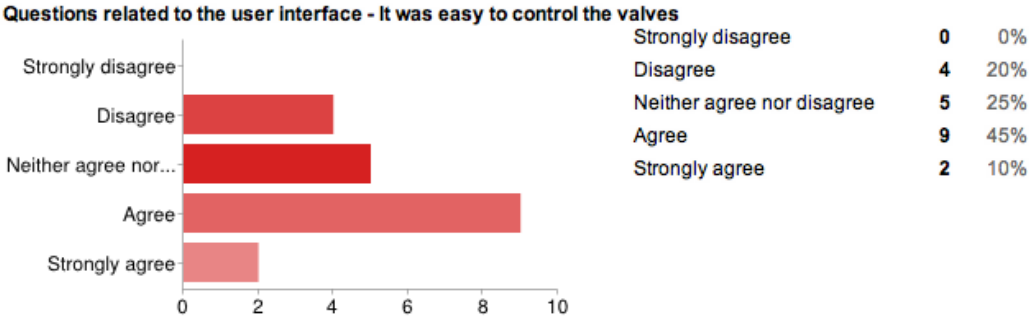


Figure 6.11: Results on whether valves were easy to control

Some participants mentioned during the interviews that adjusting the valves required too many clicks. Some suggested that it should be possible to adjust the valve slider (see Figure 4.6) without having to click on the related valve first. It was also mentioned that it was easy doing large adjustments (e.g. 20% - 60%) to the valves but doing small adjustment (e.g. 10% - 12%) was difficult.

### 6.3.2 Gameplay

Apart from the user interface, we wanted to know what the participants thought of the implemented gameplay elements, like score and feedback. More specifically, we wanted to know if the gameplay elements motivated

and helped the participants to do a better job. For more detailed information about the game elements, see Section 3.2: Gamifying the separation process.

Before the first test run in the experiment, each participant did a tutorial (in addition to receiving a verbal training) in order to learn how the separation process worked and how to control it. We wanted to know if the tutorial gave an understanding of the separation process in addition to an understanding of how to control it. 75% agreed to the statement *"The tutorial gave me an understanding of how to play the game"*, 15% were neutral. The complete results are shown in Figure 6.12.

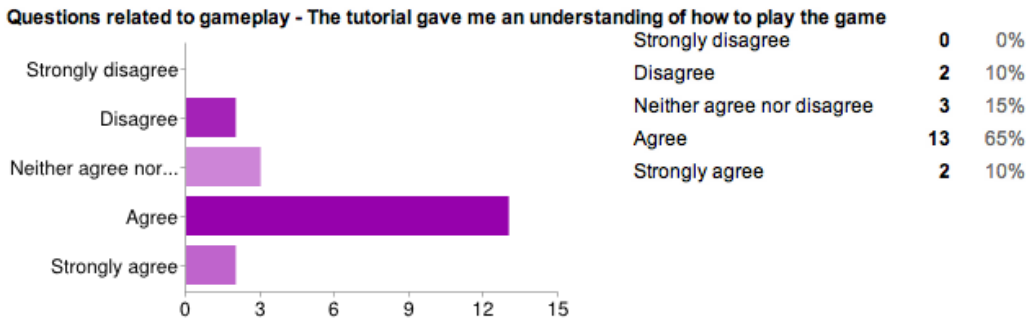


Figure 6.12: Results on the tutorial as a learning tool

Score points were one of the gameplay elements that was implemented. 80% agreed to the statement that the score points motivated them to perform better and 20% were neutral. No one disagreed to this statement. This indicates that the score points worked as a positive factor for motivation. The complete results are shown in Figure 6.13.

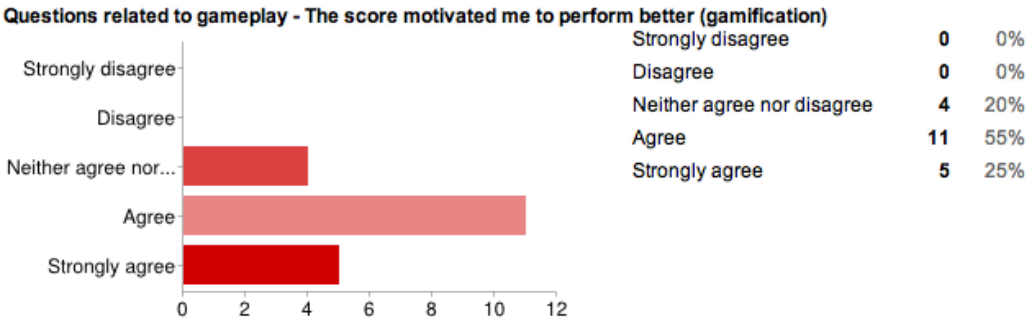


Figure 6.13: Results on score points as a motivating factor

The scores were stored in a database at the end of each run and used in the high score list. 80% agreed to the statement *"The high score list*

*motivated me to perform better"* while 20% were neutral. The complete results are shown in Figure 6.14.

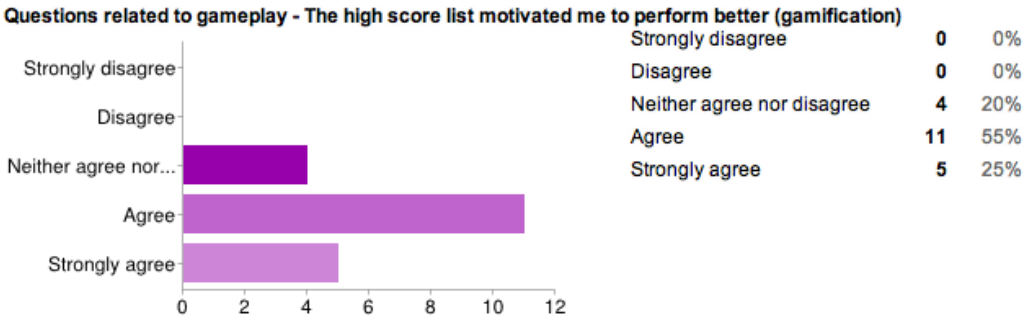


Figure 6.14: Results on the high score list as a motivating factor

Another aspect of the score that was important to examine, was whether the participants understood why they got score points, or lost them. 65% of the participants understood why they got score points, 40% of the participants understood why they lost score points. It seems that it was less intuitive to the participants why they lost score points. 20% of the participants did not understand why they lost score points, while 40% were neutral to the question *"I understood why I lost points"*. 15% did not understand why they got score points, while 20% were neutral. The complete results are shown in Figure 6.15 and Figure 6.16.

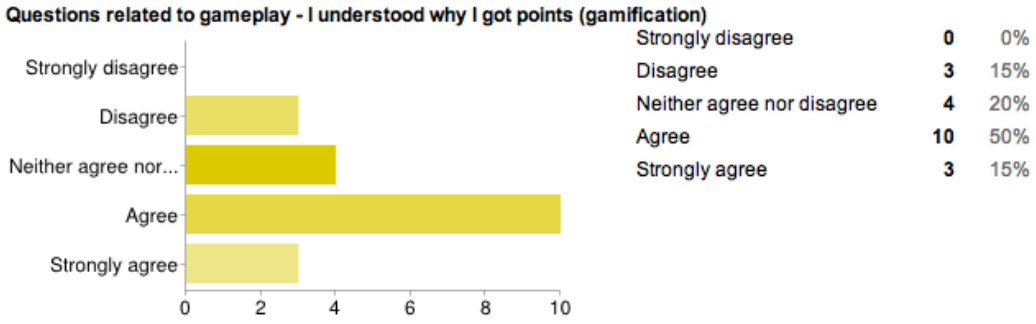


Figure 6.15: Results on whether participants understood why they got score points

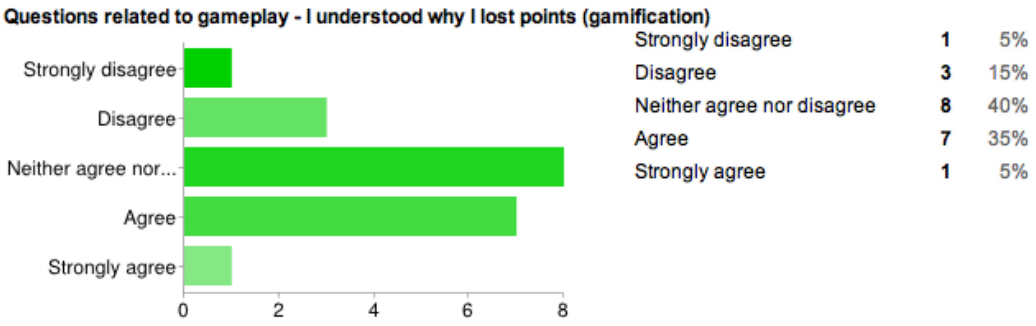


Figure 6.16: Results on whether participants understood why they lost score points

Another gameplay element that was implemented is the experience bar. When asked if the experience bar was a motivating factor for performing better, 60% agreed, 10% disagreed and 30% were neutral. The complete results are shown in Figure 6.17.

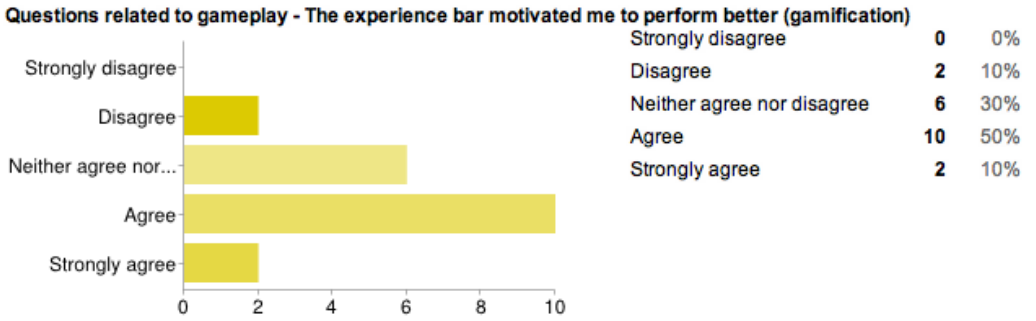


Figure 6.17: Results on the experience bar as a motivating factor

In addition to score points and the experience bar, goals were implemented for the user to complete. Completing a goal rewards the user with score points and experience points. 45% of the participants agreed to the statement *"The goals motivated me to complete them"*, while 50% were neutral. The complete results are shown in Figure 6.18.

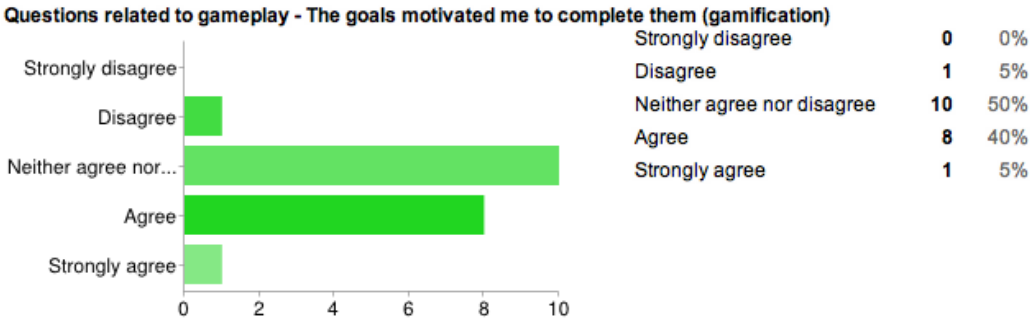


Figure 6.18: Results on motivation for completing goals

One of the things we thought would be interesting to discover was if the participants reacted to the feedback they received from the game, i.e. did they do adjustments because of the feedback they received? 80% agreed to the statement *"I did adjustments because of the feedback I received from the widget"*. The rest of the 20% were either neutral or disagreeing. The complete results are shown in Figure 6.19.

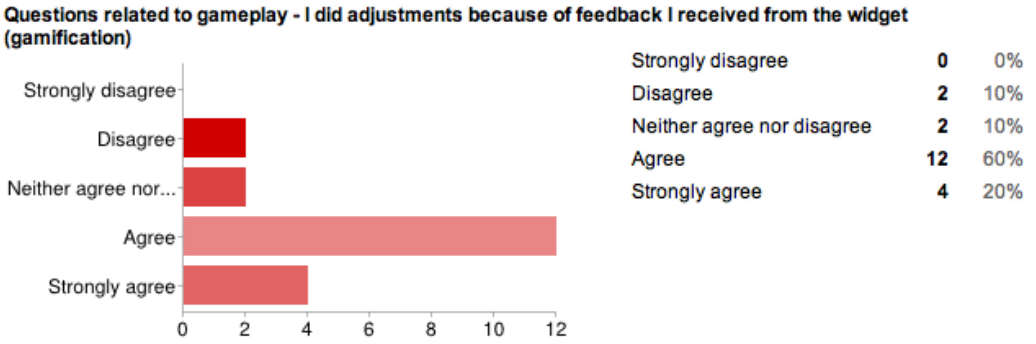


Figure 6.19: Adjustments were made because of received feedback

After each test run (with gamification) the participant got a summary of his/her performance. The participants were asked if they understood what they did right or wrong during the separation process, based on the information in the summary. 60% agreed that they understood what they did right, while 40% agreed that they understood what they did wrong. 20% did not understand what they did right (i.e. 20% disagreed to the statement *"The summary gave me an understanding of what I did right"*), while 45% did not understand what they did wrong (i.e. 45% disagreed on the statement *"The summary gave me an understanding of what I did wrong"*). The complete results are shown in Figure 6.20 and Figure 6.21.

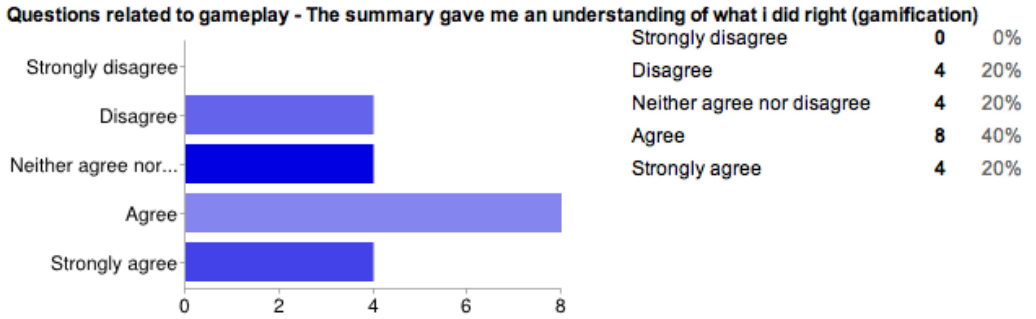


Figure 6.20: Results on whether the summary helped participants understand what they did right

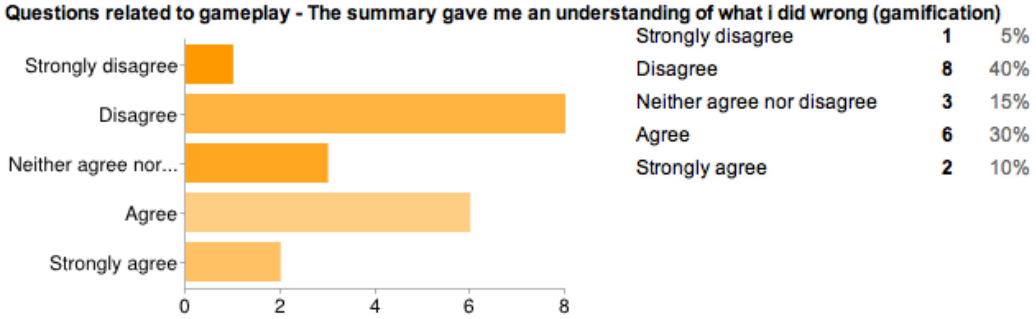


Figure 6.21: Results on whether the summary helped participants understand what they did wrong

### 6.3.3 Comparison between gamification and non-gamification

In the survey each participant was asked to compare the gamified separation process to the non-gamified (regular) separation process. 85% agreed that it was more fun to operate the separation process with gamification than without gamification. The last 15% were neutral. The complete results are shown in Figure 6.22.

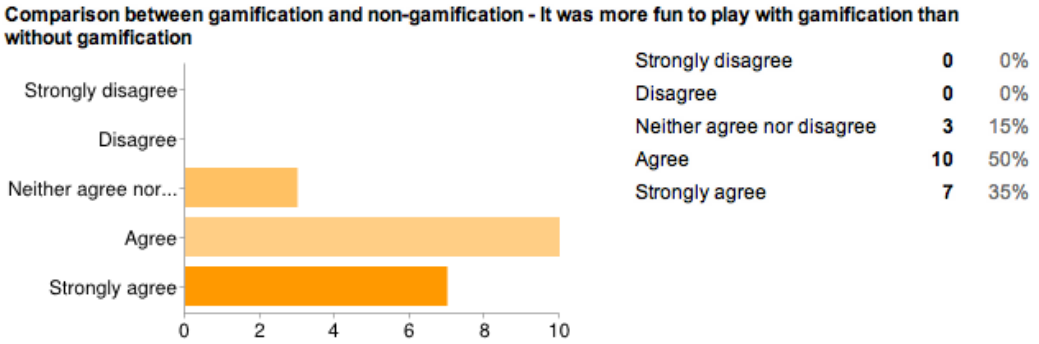


Figure 6.22: The participants thought it was more fun to play with gamification

We also wanted to know if the participants felt that they performed better with gamification. 40% agreed that they performed better with gamification than without gamification, 30% were neutral and 30% disagreed. The complete results are shown in Figure 6.23.

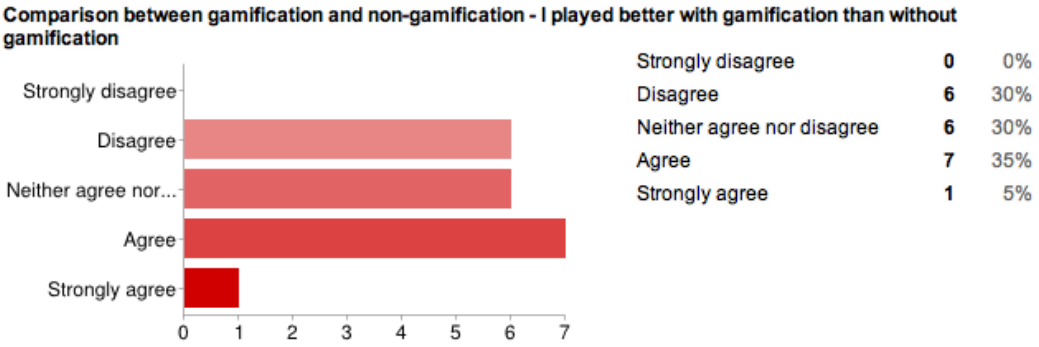


Figure 6.23: Results on whether the participants thought they played better with gamification

As mentioned earlier, gamification had to be subtle not to distract the user from the separation process. With this in mind we wanted to know if gamification was distracting. 80% disagreed to the statement *"I think gamification was distracting"*. 5% (one participant) felt that gamification actually was distracting. During the interview almost everyone said that the gamification widget's presence was not visible enough. One participant mentioned that he paid so much attention to the gamification widget that he was distracted from his work. The complete results from the survey are shown in Figure 6.24.

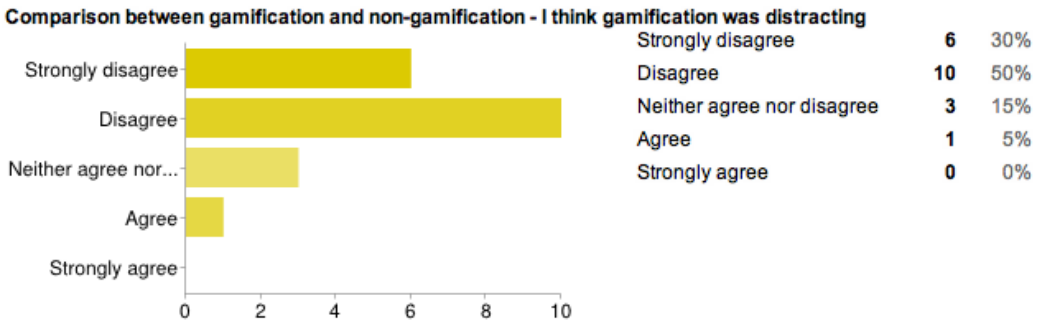


Figure 6.24: Results on whether gamification was distracting or not

Another comparison we wanted to do was whether the gamification widget as a whole was a motivating factor for performing better. 75% agreed to the statement *"The gamification widget motivated me to perform better"*. 20% were neutral. The complete results are shown in Figure 6.25.

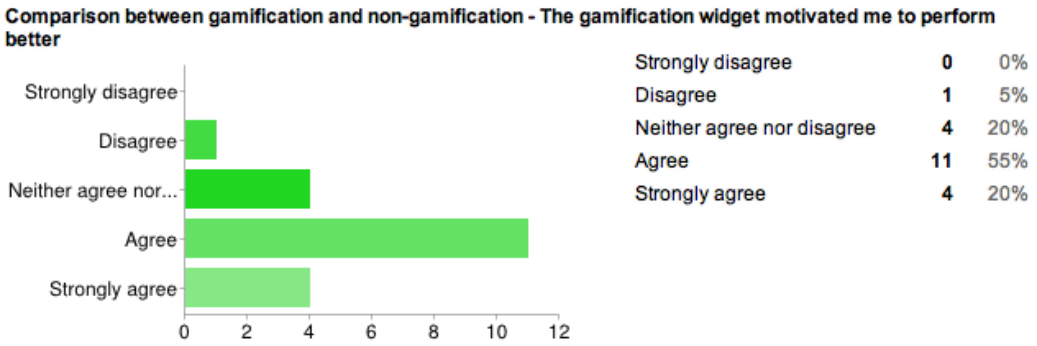


Figure 6.25: Results on whether the gamification widget was a motivating factor for performing better

In addition to discovering if gamification was motivating and fun we also wanted to determine if gamification could improve the operator's skills. RQ2 asks this question: *"Can an operator's skills be improved by gamification?"*.

50% agreed that the separation process was easier to perform with gamification than without gamification, 25% were neutral, 25% disagreed. The complete results are shown in Figure 6.26.

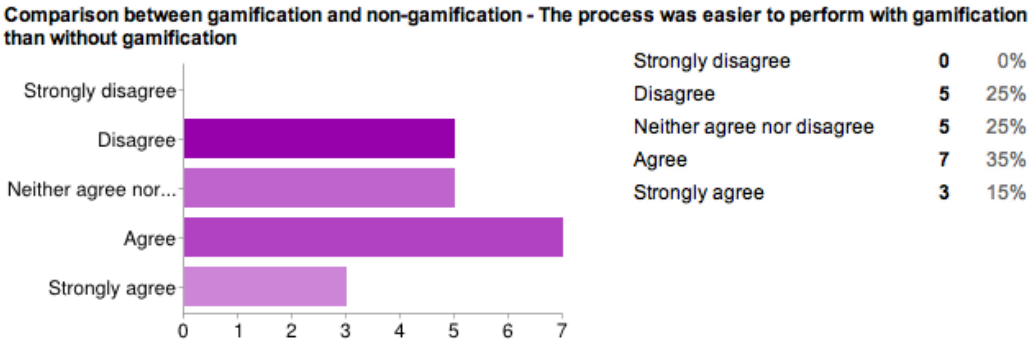


Figure 6.26: Results on whether the users thought that the separation process was easier with gamification

We also asked if the participants thought that gamification would improve their skills over time. 85% agreed to this statement, 10% disagreed. The complete results are shown in Figure 6.27.

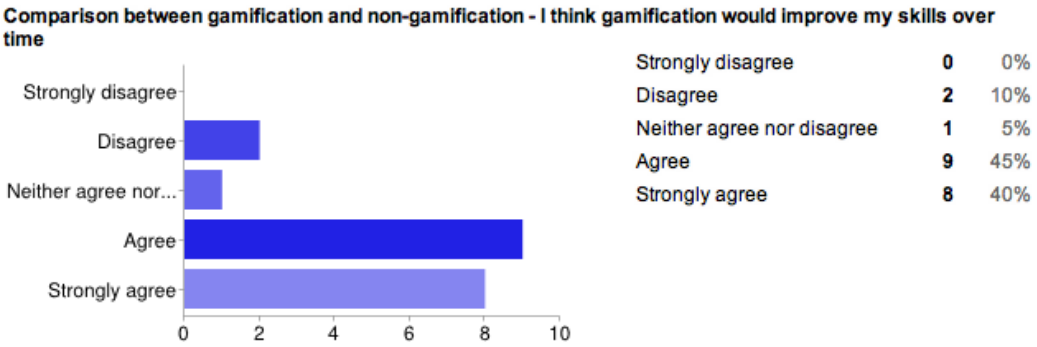


Figure 6.27: Users believed that gamification would improve their skills over time

### 6.3.4 System Usability

A System Usability Scale (SUS) was implemented as part of the survey. In accordance with John Brooke's article "SUS - A quick and dirty usability scale"[5] the System Usability Scale was put to use after each participant had the opportunity to use the system and before any debriefing or discussion[5]. The SUS is a Likert scale with ten items which gives an overall view of the subjective assessments of usability[5]. The Likert scale uses a 5 or 7 point scale which indicates the degree of agreement or disagreement to a statement[5]. A 5 point scale from "Strongly disagree" to "Strongly agree" was used.

The SUS uses a single number which represents a composite measure of the overall usability of the system being examined[5]. Calculation of the SUS score is done by first summing the score contribution from each item (i.e. each statement, see Table 6.5). Each item's score contribution ranges from 0 to 4. For items 1, 3, 5, 7 and 9, the score contribution is the scale position (i.e. "Strongly disagree" is position 1, "Strongly agree" is position 5). For items 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position. Then the sum of the scores are multiplied by 2,5 to obtain the overall value of system usability. The SUS have a score range of 0 to 100[5]. The results from the System Usability Scale are shown in Table 6.5.

| | **Question** | **Score** | **Average** |
|---|---|---|---|
| I 1: | I think that I would like to use this system frequently | 6,13 | 2,45 |
| I 2: | I found the system unnecessarily complex | 6,75 | 2,70 |
| I 3: | I thought the system was easy to use | 6,38 | 2,55 |
| I 4: | I think that I would need the support of a technical person to be able to use this system | 7,25 | 2,90 |
| I 5: | I found the various functions in this system were well integrated | 6,13 | 2,45 |
| I 6: | I thought there was too much inconsistency in this system | 6,75 | 2,70 |
| I 7: | I would imagine that most people would learn to use this system very quickly | 5,50 | 2,20 |
| I 8: | I found the system very cumbersome to use | 6,13 | 2,45 |
| I 9: | I felt very confident using the system | 3,88 | 1,55 |
| I 10: | I needed to learn a lot of things before I could get going with this system | 6,00 | 2,40 |

Table 6.5: SUS score

The total score for the SUS adds up to 60,79 (out of 100) which indicates there is room for improvement.

## 6.4 Results from the interviews

In addition to using data from the system, the survey and the quiz to answer our research questions, we also used what was said in the interviews. This section presents some of the most interesting statements.

One of the questions we asked was *"Do you think gamification was distracting? Why, why not? Follow up: In what way was it distracting?"*. Almost everyone, except one participant, felt that the presence of the gamification widget was too low. The one participant that thought gamification was too distracting stated that the goals and other motivating factors distracted him from paying attention to the separation process. He felt that it was especially distracting when he was notified about completing a goal or when he got feedback. At one point in the test run he explored the high score list in the gamification widget during which time oil mixed with water. The ones that said gamification was not distracting enough, mentioned that the widget was too far away from their focus area and that the widget did not do enough to capture their attention. The use of more saturated colours, moving the gamification widget closer to the focus area, the use of sound effects (e.g. to alert the user of given feedback or completed goals), dedication of more space to the widget and usage of visual feedback close to the relative element were some of the proposals made to improve the presence of the gamification elements.

Another question the participants were asked was *"Do you feel that you were more in control with gamification? Why, why not?"*. Five participants did not feel that they had more control when operating the separation process with gamification, the other 15 were either neutral or they felt they had more control with gamification. The feedback given (from the gamification widget) was the main reason that participants felt they were more in control with gamification. Another reason for this sense of control was the score. Participants understood that they did something right (or wrong) based on the score increasing or decreasing. Those who said they were not in more control with gamification, were the ones who did the separation process with gamification first. They said that they had more control in their second test run (without gamification), because of the experience gained from the first test run. In addition, some of the participants that did not feel that they had more control with gamification did not pay attention to the gamification widget.

We also wanted to know if the participants thought they performed better because of gamification. The participants were asked *"Do you feel that your skill was improved because of gamification? Why, why not?"*. Most participants answered that it was difficult to determine whether it was gamification

or experience that improved their skills. But some participants mentioned that the score motivated them to do a better job, which may in time have improved their skills. Some of the participants that noticed the feedback they received, said that the feedback was imprecise and that they missed feedback in some situations which may have affected their skill improvement. In other situations feedback was unexpected.

In addition to asking about skill improvement, the participants were asked about their understanding of the separation process; *"Do you feel that you understood the separation process better because of the training given (both verbal and the tutorial)? Why, Why not? Which method was most effective?"*. Some participants said that they felt the explanation of the separation process and the tutorial gave them an understanding of the separation process. We also asked *"Do you feel that you now understand the separation process better after finishing this experiment? Why, why not?"*. Most participants said that they felt they understood the separation process better after the experiment. Whether this was because of the separation process explanation and tutorial, the experience gained or gamification is unknown. However, results from the quiz indicates that gamification did not have an effect on the participants understanding.

We were also curious about what advantages the participants saw in having or not having gamification. We asked *"What advantages is there in having gamification?"* and *"What advantages is there in not having gamification?"*. Most participants felt that having gamification made the separation process more fun, the score was appealing, gamification was motivating, having a high score list opened for competition (which some participant mentioned was not positive) and the feedback gave an understanding of correct or incorrect actions. Most participants did not see any advantages with not having gamification, but it was mentioned that not having the gamification widget could be less distracting. An interesting statement was that by not having the gamification widget, one would not feel as much pressure, or need, to perform well.

# Chapter 7

# Discussion

In this chapter we will discuss the results from the conducted experiment. The discussion is separated into motivation, skill and understanding. In addition, criticism to the conducted research is discussed.

## 7.1 Improved motivation

The one area where gamification seemed to have an effect was on the participant's motivation. Both in the survey and in the interview we found evidence of this. The survey revealed that 80% of the participants agreed that the score in the widget motivated them to perform better. An equal amount of participants agreed that the high score list motivated them.

High scores can be a source of bragging for the player, which can be a source of motivation[6]. Scoring is also a form for motivation which Dantas et al. describes as one of the keys for educational success[9]. High scores and scoring are related to the self-efficacy paradigm, additionally scoring is indirectly related to the feedback paradigm, i.e. the operator knows if he is doing well or not by looking at the score. Both the self-efficacy and the feedback paradigm is described in Section 2.2.4: Important game mechanics for learning.

The experience bar seemed to be less understood and noticed by the participants. Only 60% agreed that the experience bar had motivated them. The reasons for this could be that the progression of the experience bar was slow and it was difficult to advance more than one level during the test. The advancement problem could be solved by having longer test runs or better tuning of the progression.

85% of the participants agreed that it was more fun to play with gamification than without. Fun is something that can affect the engagement of

the users[30].

The least motivating game element were the goals, which are one of the key characteristics of a game and are important for motivation[24, ch. 5, p. 1]. 45% of the participants thought that the goals were motivating, while 50% were neutral. Most participants did not notice when they completed a goal and most participants did not explore the goals. We believe that if the progressions of the goals had been easily accessible for the participants at all times, the goals would have been more motivating. Mayo states that an important game mechanic for learning is self-efficacy, i.e. to be awarded with points, levels, etc. at positive decision points to encourage a player to keep playing so that he may succeed more often[18]. We believe that motivation would improve if it had been more obvious to the participants when they completed a goal (or got positive feedback) and what the reward for completion was.

As a conclusion to this section, we believe, based on the results, that gamification was motivating for the participants, but that some motivating elements could have been better implemented.

## 7.2 No skill improvement

Results indicates that there were no improvements of the participants skills because of gamification. The results actually showed that the group that operated the separation process without gamification first (group RF), on average performed better than the group that operated the separation process with gamification first (group GF). This difference was however not statistically significant. We believe that the reasons there were no improvement in performance when operating the separation process with gamification, was uncovered in the survey and interview.

In the survey it was uncovered that participants more often noticed the alarms (that were present both with gamification and without gamification) than the feedback they received from the gamification widget. 85% of the participants noticed when they received alarms compared to 65% that noticed when they received feedback. It is important that games that teach or train give continuous feedback on the user's performance[18], if this feedback goes unnoticed, then the game's learning potential might be diminished. Had the physical placement of the feedback been closer to the focus area and the intrusiveness of the feedback been higher, more participants might have noticed the feedback and their skills might have improved.

Some of the participants that noticed the feedback said that they missed feedback in some situations (i.e. they wanted feedback in situations where it

was not provided) and that in other situations feedback was not expected. Providing an appropriate amount of feedback in a game is important, because either too little or too much can quickly lead to frustration for the player[24, ch. 5, p. 14].

65% of the participants understood why they received score points. Scoring is a form for assessment. A scoring system teaches a player what is important within the game. A positive score indicates a good choice, a negative score a bad choice, and no score at all indicates that the actions is probably unimportant[6].

It was also mentioned in the interviews that the presence of the gamification widget was to low and that it would have been easier to interact with if it had been physically closer to the separator, i.e. more centered in the window. This is also something that we can agree with the participants on, although there were reasons for the placement and the subtleness of the widget. Had the gamification widget been more present in the application, the effectiveness of gamification might have improved.

We did not get to test gamification over time, but 85% of the participants answered in the survey that they think that gamification would improve their skills over time.

To conclude this section, there was no improvement in participants' skill because of the gamified elements. Reasons for this could be that feedback was imprecise and difficult to notice.

## 7.3 No improvement of understanding

Results from the quiz showed that there was no statistically significant improvement in understanding of the separation process when operating it with gamification. We believe that had the feedback been richer, i.e. more precise, had there been more feedback on different events and had the feedback been more present, gamification could have been beneficial for the understanding of the separation process.

The survey revealed that only 30% of the participants agreed that they spent a lot of time looking at the widget and only 20% agreed that they spent a lot of time interacting with the widget. Had the participants spent more time looking at and interacting with the widget, it is possible that they would understand more of their feedback and in turn get a better understanding of the separation process.

Another reason for why gamification failed to improve understanding might be the lack of accurate feedback. Several participants mentioned in the interview that the feedback they received was sometimes unexpected

and sometimes imprecise. When looking at the feedback given to the participants, we can agree to this statement, e.g. the gamification widget gave users feedback on closing valves when it was not strictly necessary. This was sometimes not entirely true as it was sometimes a good idea to open valves pre-emptively to prepare for incoming fluid. Michael and Chen underlines the importance of appropriate feedback[6].

In conclusion, there were no improvement in the participants understanding because of the gamified elements. The reason for this lack of improvement can be attributed to several flaws in the implementation, mainly the subtleness of the widget and the inaccuracy of the feedback.

## 7.4 Criticism of the research

The results found from the conducted research was affected by the way the research was designed and executed. The system (with gamified elements) is meant to be used by process controllers/operators, for training, motivation and learning and should thus have been tested by that user group. Due to constraints on resources we could only test the system and the implemented gamification on students, which were not the targeted user group.

There was also a flaw in the design of the research. The separation process was tested on two groups consisting of 10 participants each. The two groups did the separation process twice, once with gamification, once without gamification. What separated the groups were in which order the separation process was done, i.e. with or without gamification first. Had there been another test group, i.e. a group that did the separation process without gamification both times, we might have drawn more conclusions about the improvements between the first and second test run.

The duration of each test run was 10 minutes. Had the duration been longer we might have had a better idea whether gamification improved motivation, skill and understanding. In an hour long test run, game mechanics like goals and ranks might have been more effective.

The behaviour of the gas in the simulator was not very intuitive. This might have affected the results on gas production and gas quality for the test participants.

# Chapter 8

# Conclusion and further work

This thesis has focused on serious games and gamification in a process control system. We cooperated with ABB to gamify an oil and gas separation process that was simulated and implemented into a prototype of one of their process control systems.

When we started our work on this thesis, we first defined three research questions. This was followed by examining serious games, gamification and other related areas. We also found examples of existing solutions within these areas and collected results from previously conducted experiments. We did not find any information on serious games or gamification directly related to a process control system.

When background information had been collected and evaluated, we started the implementation of a gamified separation process.

After implementation was done, we conducted the experiment and 20 people (mostly students) participated. These 20 participants were divided into two groups of 10 participants. Each group did the separation process twice, one time with gamification, one time without gamification. What distinguished the two groups were in which order they did the separation process, with gamification first or without gamification first. Each participant also answered a quiz, a survey and an interview.

After the experiment, data was collected and analysed to answer our research questions:

**RQ1:** *Can a gamified separation process improve an operator's motivation?*

**RQ2:** *Can an operator's skills be improved by gamification?*

**RQ3:** *Can gamification improve an operator's understanding of a given subject?*

## 8.1 Improved motivation

To answer RQ1 data from the survey and the interviews was used. We concluded that the implemented game elements, especially the score points and the high score list, motivated the participants to perform better. The goals were the least motivating factor for the participants, followed by the experience bar. Some participants mentioned in their interview that they felt a sense of progression because of the experience bar and the score points. Although results indicate that the implemented game elements improved the participants' motivation, we believe that the use of game elements for motivation could be even better.

## 8.2 No skill improvement

To answer RQ2, data from the created system was used. The results showed that there were no statistical significant positive effect by doing the separation process with gamification. The results also showed that there were no statistical significant improvement between the two test runs within the groups because of gamification. In the interviews some participants stated that they felt more in control when doing the separation process with gamification. Both groups improved from the first run to the second run, this was probably due to experience from the first test run. We cannot be certain of this statement since we did not have a third test group that operated the separation process without gamification both times.

## 8.3 No improvement of understanding

To answer RQ3 data from the quiz was used. We compared the results from the two groups and found that the difference of 0,1 in score was not statistically significant. Although, some participants stated in the interview that they understood when they did something wrong (or right) because of the feedback.

## 8.4 Further work

Based on the results from the conducted experiment presented in Chapter 6: Results and discussed in Chapter 7: Discussion, there are improvements that can be done to make gamification in a process control system a tool for learning, motivation and skill development.

First and foremost more research is needed. Not necessarily on gamification in general, but on gamification in process control systems where gamification needs to be subtle and the process at hand is in focus and of grave severity. One of the challenges of this project was that gamification had to be subtle and results from the experiment indicate that gamification was too subtle. We were given one limited (and predetermined) space to implement the gamification widget and would suggest that, for similar projects in the future, the game elements gets more attention from the system designers, even though the process has the highest priority. A suggestion is to increase the presence of the game elements so that the user has a higher chance of noticing them. This may improve user skill, understanding and motivation. Improvements can be done by moving the game elements closer to the user's focus area, for example by showing icons that relates to a process element next to that process element. Figure 8.1 illustrates this improvement compared to the current visualization presented in Figure 8.2.

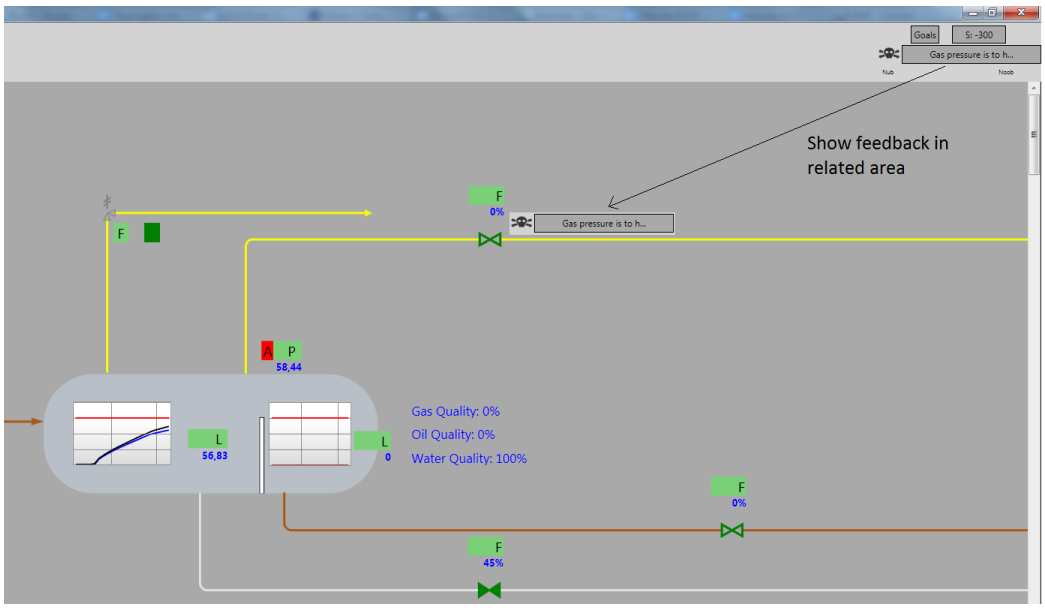


Figure 8.1: Suggested improvement to feedback visualization

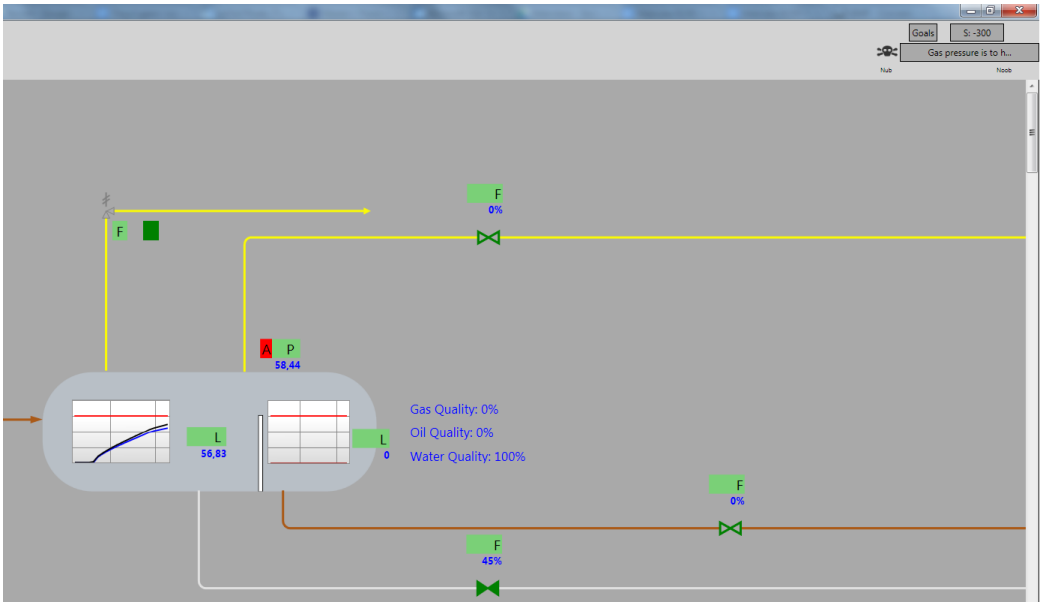


Figure 8.2: Current visualization

At the same time, notifications from the game elements (in this case feedback and notification for completing a goal) can be made more visible by using e.g. animations, sound effects, or highly saturated colours. We used flashing buttons to indicate that feedback had been given or that a goal had been completed. We believe that the duration of the flashing was to short, the colour not saturated enough, the feedback not intrusive enough and that the placement the gamification widget was too far away from the participant's focus area. Another suggestion is to use the space that is available, use the entire interface if possible (and necessary), so that the user never misses a notification or any other important information given from the implemented game elements.

Domain knowledge of the process at hand is also necessary. We agree with Reidel and Hauge that *"serious games are context dependent and require subject knowledge for their development"*[25], especially if the users of a system are to learn from the gamified elements. We observed from the experiment that feedback given from the system was not precise and that the feedback should have been more detailed. Therefore we suggest that the feedback given is as precise and rich as possible so that the users can learn from their actions. A reason for why the feedback is given is also necessary so that the user can learn from his mistake (or success). We also suggest that more feedback is given, i.e. feedback on more events. If someone was to further develop this system or design a new similar system, we suggest the

following:

**Greater focus on gamification:**

With this project there was a constraint on the use of gamification; we had a limited dedicated screen space. Our first recommendation is that gamification design gets a higher priority, and that you use knowledge from serious games, gamification and related fields.

**Richer feedback:**

First of all, you (or someone on your team) need domain knowledge[25]. If you are to create a fish farming simulator, you need to acquire knowledge about fish farming. When this knowledge is acquired, you need to use this knowledge in the game. Tell the user what he does right or wrong and tell him why it was right or wrong. The feedback implemented in our project was rather basic and there was not enough feedback. Therefore, give enough and appropriate feedback[24, ch. 5, p. 14][6].

**Make sure that gamification is beneficial:**

You want to make sure that the user benefits from the implemented gamification elements. Make sure that he notices changes in the user interface, e.g. new feedback, goal completed, etc. We suggest that you use the entire screen space so that no feedback goes unnoticed. Make sure to test the system properly (on the target user group) and make sure those users notices and understands the feedback and other game elements.

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# Appendix A

# Acronyms

**2D:** Two dimensional

**CD:** Compact Disc

**CLR:** Common Language Runtime

**COTS:** Commercial Off The Shelf

**DGBL:** Digital Game-Based Learning

**GBL:** Game-Based Learning

**GUI:** Graphical User Interface

**HTML:** HyperText Markup Language

**IL:** Intermediate Language

**KPI:** Key Performance Indicator

**LAN:** Local Area Network

**MIT:** Massachusetts Institute of Technology

**MMOG:** Massively Multiplayer Online Game

**MS:** Microsoft

**ROM:** Read Only Memory

**RPG:** Role Playing Game

**RTS:** Real Time Strategy

| | |
|---|---|
| **SQL:** | Structured Query Language |
| **SUS:** | System Usability Scale |
| **TV:** | Television |
| **UI:** | User Interface |
| **WAN:** | Wide Area Network |
| **WebGL:** | Web Graphics Library |
| **WPF:** | Windows Presentation Foundation |
| **XAML:** | Extensible Application Markup Language |
| **XML:** | Extensible Markup Language |

# Appendix B

# Questions from the survey

**Questions related to the user interface** *

| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| I noticed when I received feedback (gamification) | ○ | ○ | ○ | ○ | ○ |
| I noticed when I received alarms | ○ | ○ | ○ | ○ | ○ |
| It was easy to control the valves | ○ | ○ | ○ | ○ | ○ |
| The application gave me a good overview of what was happening | ○ | ○ | ○ | ○ | ○ |
| I understood what was happening in the separator | ○ | ○ | ○ | ○ | ○ |
| I spent a lot of time looking at the widget (gamification) | ○ | ○ | ○ | ○ | ○ |
| I spent a lot of time interacting with the widget (gamification) | ○ | ○ | ○ | ○ | ○ |
| I noticed when i achieved a goal (gamification) | ○ | ○ | ○ | ○ | ○ |

**Questions related to gameplay** *

| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| The score motivated me to perform better (gamification) | ○ | ○ | ○ | ○ | ○ |
| The experience bar motivated me to perform better (gamification) | ○ | ○ | ○ | ○ | ○ |
| The goals motivated me to complete them (gamification) | ○ | ○ | ○ | ○ | ○ |
| The high score list motivated me to perform better (gamification) | ○ | ○ | ○ | ○ | ○ |
| The summary gave me an understanding of what i did right (gamification) | ○ | ○ | ○ | ○ | ○ |
| The summary gave me an understanding of what i did wrong (gamification) | ○ | ○ | ○ | ○ | ○ |
| I did adjustments because of feedback I received from the widget (gamification) | ○ | ○ | ○ | ○ | ○ |
| I understood why I got points (gamification) | ○ | ○ | ○ | ○ | ○ |
| I understood why I lost points (gamification) | ○ | ○ | ○ | ○ | ○ |
| The tutorial gave me an understanding of how to play the game | ○ | ○ | ○ | ○ | ○ |
| The process was easy to understand | ○ | ○ | ○ | ○ | ○ |

**Comparison between gamification and non-gamification** *

| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| It was more fun to play with gamification than without gamification | ○ | ○ | ○ | ○ | ○ |
| I played better with gamification than without gamification | ○ | ○ | ○ | ○ | ○ |
| I think gamification was distracting | ○ | ○ | ○ | ○ | ○ |
| The gamification widget motivated me to perform better | ○ | ○ | ○ | ○ | ○ |
| The process was easier to perform with gamification than without gamification | ○ | ○ | ○ | ○ | ○ |
| I think gamification would improve my skills over time | ○ | ○ | ○ | ○ | ○ |

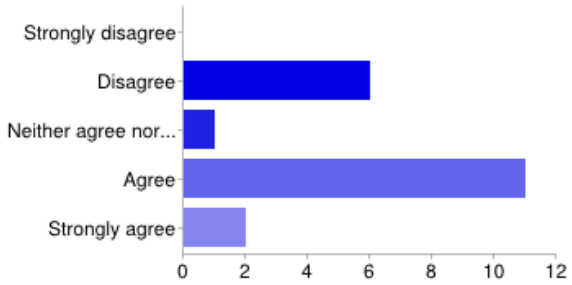
**System usability scale (SUS) ***

| | Strongly disagree | Disagree | Neither agree nor disagree | Agree | Strongly agree |
|---|---|---|---|---|---|
| I think that I would like to use this system frequently | ○ | ○ | ○ | ○ | ○ |
| I found the system unnecessarily complex | ○ | ○ | ○ | ○ | ○ |
| I thought the system was easy to use | ○ | ○ | ○ | ○ | ○ |
| I think that I would need the support of a technical person to be able to use this system | ○ | ○ | ○ | ○ | ○ |
| I found the various functions in this system were well integrated | ○ | ○ | ○ | ○ | ○ |
| I thought there was too much inconsistency in this system | ○ | ○ | ○ | ○ | ○ |
| I would imagine that most people would learn to use this system very quickly | ○ | ○ | ○ | ○ | ○ |
| I found the system very cumbersome to use | ○ | ○ | ○ | ○ | ○ |
| I felt very confident using the system | ○ | ○ | ○ | ○ | ○ |
| I needed to learn a lot of things before I could get going with this system | ○ | ○ | ○ | ○ | ○ |

# Appendix C

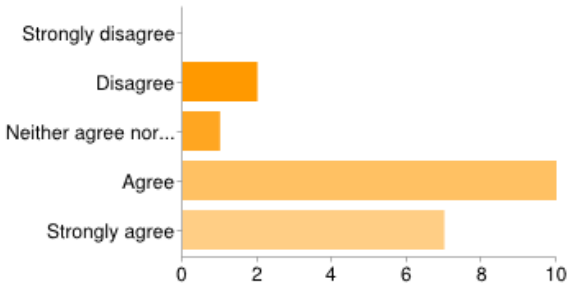
# Results from the survey

**Questions related to the user interface - I noticed when I received feedback (gamification)**



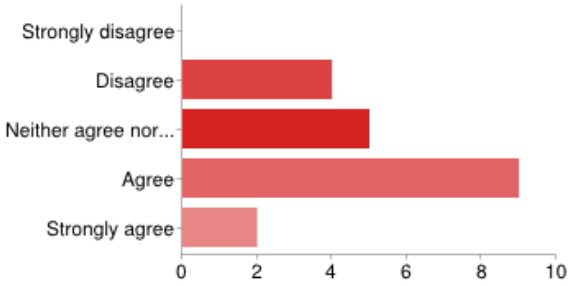

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 6 | 30% |
| Neither agree nor disagree | 1 | 5% |
| Agree | 11 | 55% |
| Strongly agree | 2 | 10% |

**Questions related to the user interface - I noticed when I received alarms**



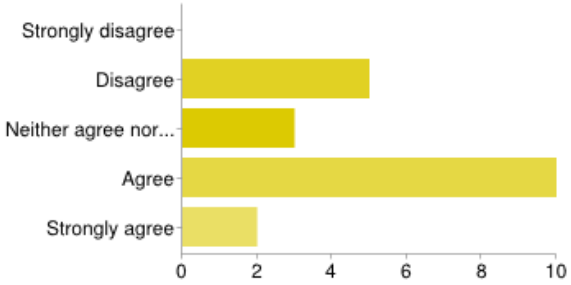

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 1 | 5% |
| Agree | 10 | 50% |
| Strongly agree | 7 | 35% |

**Questions related to the user interface - It was easy to control the valves**



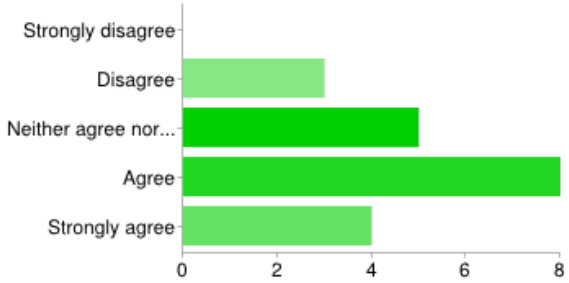

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 4 | 20% |
| Neither agree nor disagree | 5 | 25% |
| Agree | 9 | 45% |
| Strongly agree | 2 | 10% |

**Questions related to the user interface - The application gave me a good overview of what was happening**



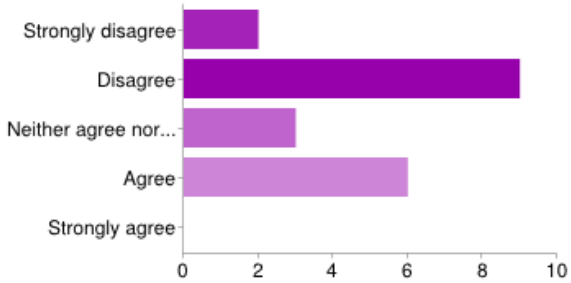

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 5 | 25% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 10 | 50% |
| Strongly agree | 2 | 10% |

**Questions related to the user interface - I understood what was happening in the separator**



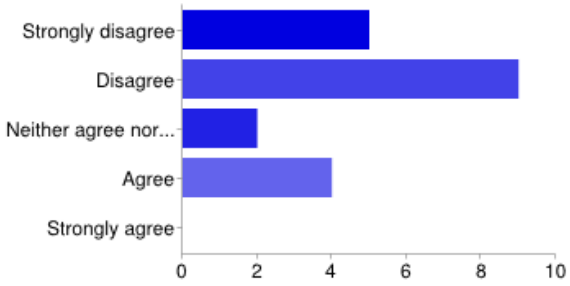

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 3 | 15% |
| Neither agree nor disagree | 5 | 25% |
| Agree | 8 | 40% |
| Strongly agree | 4 | 20% |

**Questions related to the user interface - I spent a lot of time looking at the widget (gamification)**



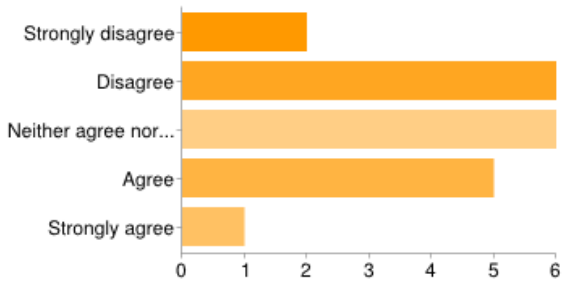

| | | |
|---|---|---|
| Strongly disagree | 2 | 10% |
| Disagree | 9 | 45% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 6 | 30% |
| Strongly agree | 0 | 0% |

**Questions related to the user interface - I spent a lot of time interacting with the widget (gamification)**



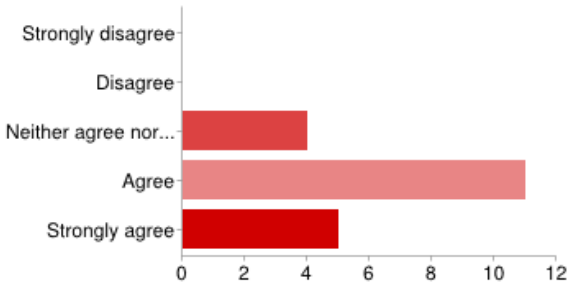

| | | |
|---|---|---|
| Strongly disagree | 5 | 25% |
| Disagree | 9 | 45% |
| Neither agree nor disagree | 2 | 10% |
| Agree | 4 | 20% |
| Strongly agree | 0 | 0% |

**Questions related to the user interface - I noticed when i achieved a goal (gamification)**



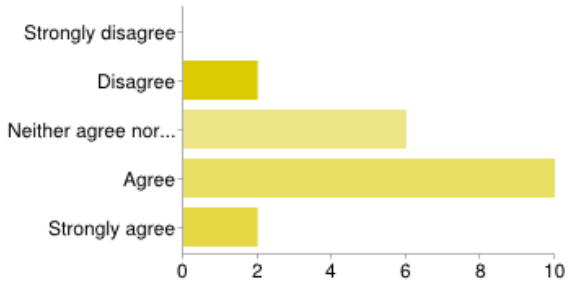

| | | |
|---|---|---|
| Strongly disagree | 2 | 10% |
| Disagree | 6 | 30% |
| Neither agree nor disagree | 6 | 30% |
| Agree | 5 | 25% |
| Strongly agree | 1 | 5% |

**Questions related to gameplay - The score motivated me to perform better (gamification)**



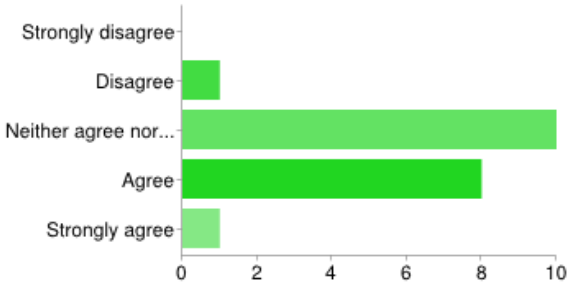

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 0 | 0% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 11 | 55% |
| Strongly agree | 5 | 25% |

**Questions related to gameplay - The experience bar motivated me to perform better (gamification)**



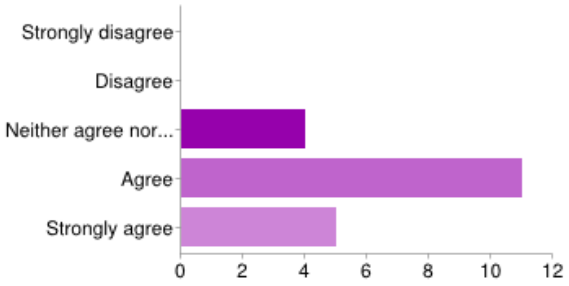

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 6 | 30% |
| Agree | 10 | 50% |
| Strongly agree | 2 | 10% |

**Questions related to gameplay - The goals motivated me to complete them (gamification)**



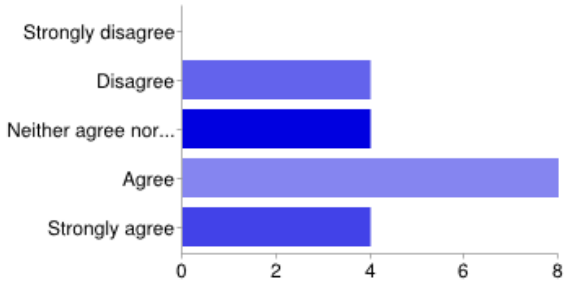

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 1 | 5% |
| Neither agree nor disagree | 10 | 50% |
| Agree | 8 | 40% |
| Strongly agree | 1 | 5% |

**Questions related to gameplay - The high score list motivated me to perform better (gamification)**



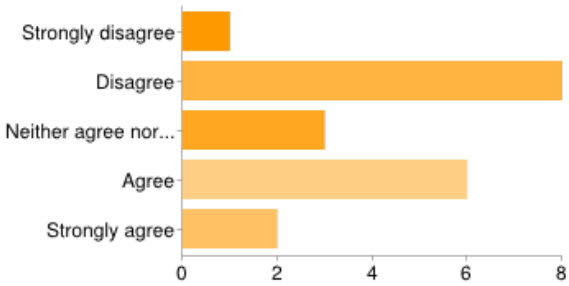

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 0 | 0% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 11 | 55% |
| Strongly agree | 5 | 25% |

**Questions related to gameplay - The summary gave me an understanding of what i did right (gamification)**



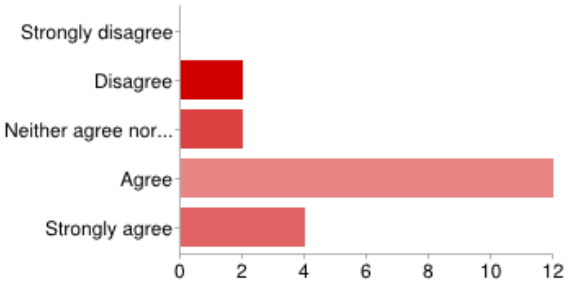

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 4 | 20% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 8 | 40% |
| Strongly agree | 4 | 20% |

**Questions related to gameplay - The summary gave me an understanding of what i did wrong (gamification)**



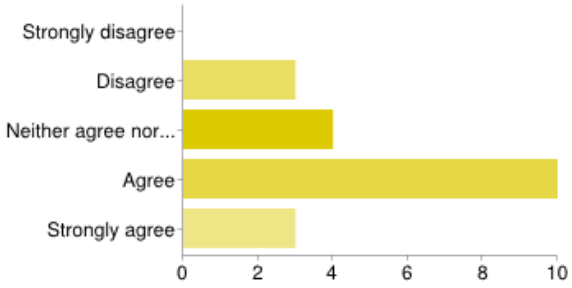

| | | |
|---|---|---|
| Strongly disagree | 1 | 5% |
| Disagree | 8 | 40% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 6 | 30% |
| Strongly agree | 2 | 10% |

**Questions related to gameplay - I did adjustments because of feedback I received from the widget (gamification)**



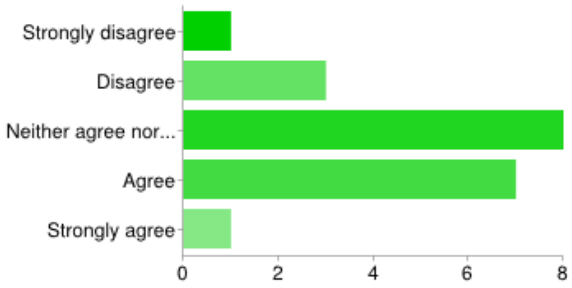

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 2 | 10% |
| Agree | 12 | 60% |
| Strongly agree | 4 | 20% |

**Questions related to gameplay - I understood why I got points (gamification)**



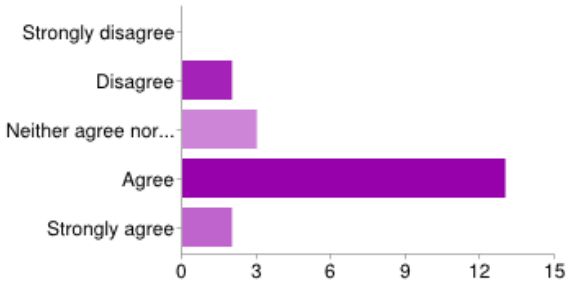

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 3 | 15% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 10 | 50% |
| Strongly agree | 3 | 15% |

**Questions related to gameplay - I understood why I lost points (gamification)**



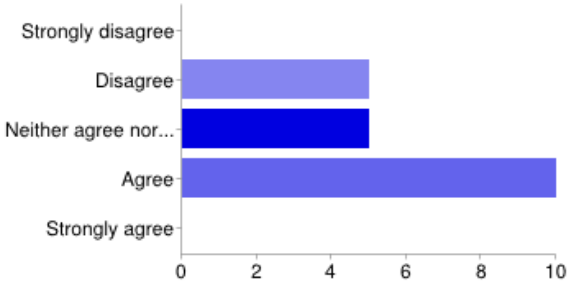

| | | |
|---|---|---|
| Strongly disagree | 1 | 5% |
| Disagree | 3 | 15% |
| Neither agree nor disagree | 8 | 40% |
| Agree | 7 | 35% |
| Strongly agree | 1 | 5% |

**Questions related to gameplay - The tutorial gave me an understanding of how to play the game**



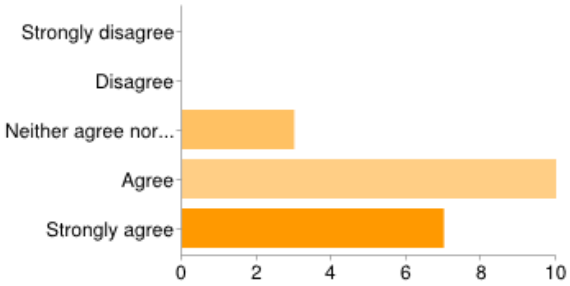

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 13 | 65% |
| Strongly agree | 2 | 10% |

**Questions related to gameplay - The process was easy to understand**



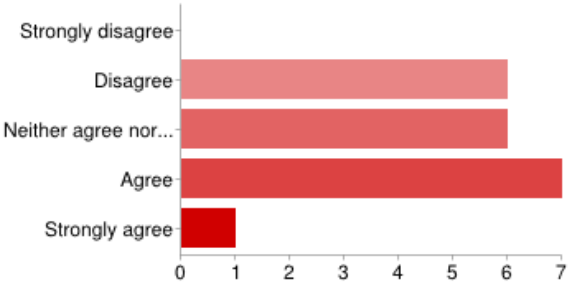

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 5 | 25% |
| Neither agree nor disagree | 5 | 25% |
| Agree | 10 | 50% |
| Strongly agree | 0 | 0% |

**Comparison between gamification and non-gamification - It was more fun to play with gamification than without gamification**



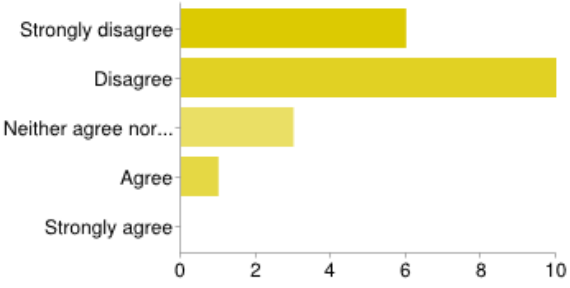

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 0 | 0% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 10 | 50% |
| Strongly agree | 7 | 35% |

**Comparison between gamification and non-gamification - I played better with gamification than without gamification**



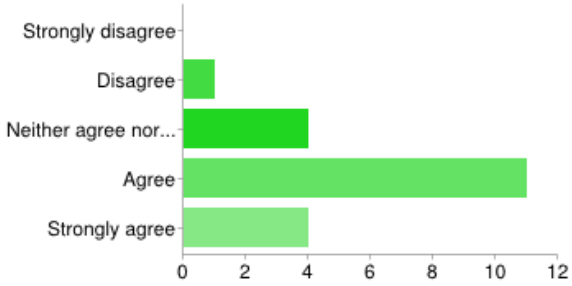

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 6 | 30% |
| Neither agree nor disagree | 6 | 30% |
| Agree | 7 | 35% |
| Strongly agree | 1 | 5% |

**Comparison between gamification and non-gamification - I think gamification was distracting**



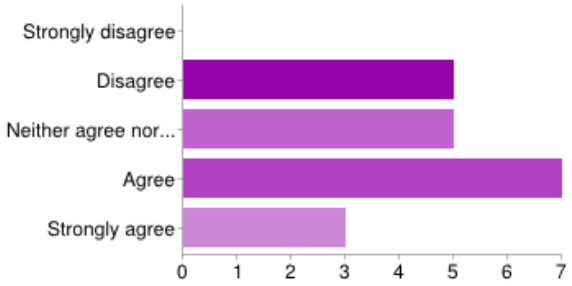

| | | |
|---|---|---|
| Strongly disagree | 6 | 30% |
| Disagree | 10 | 50% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 1 | 5% |
| Strongly agree | 0 | 0% |

**Comparison between gamification and non-gamification - The gamification widget motivated me to perform better**



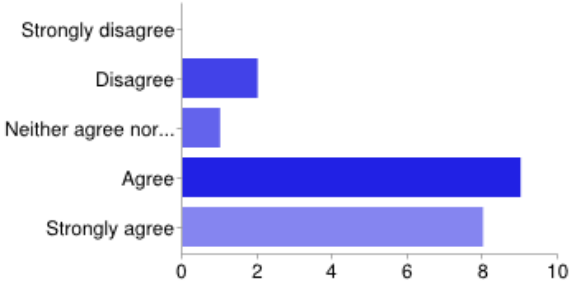

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 1 | 5% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 11 | 55% |
| Strongly agree | 4 | 20% |

**Comparison between gamification and non-gamification - The process was easier to perform with gamification than without gamification**



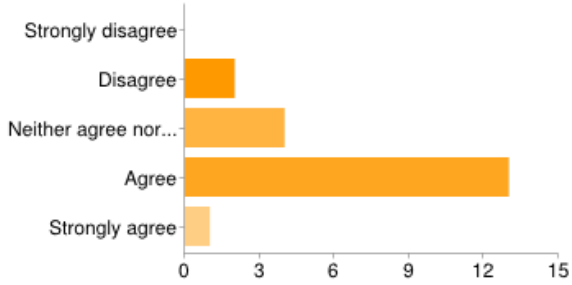

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 5 | 25% |
| Neither agree nor disagree | 5 | 25% |
| Agree | 7 | 35% |
| Strongly agree | 3 | 15% |

**Comparison between gamification and non-gamification - I think gamification would improve my skills over time**



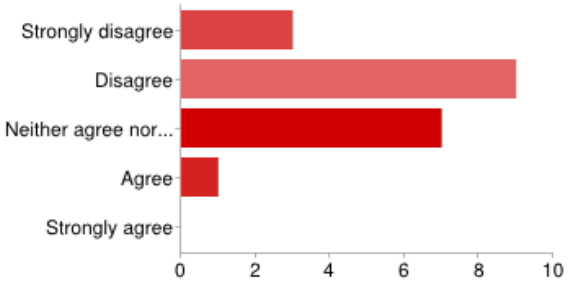

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 1 | 5% |
| Agree | 9 | 45% |
| Strongly agree | 8 | 40% |

**System usability scale (SUS) - I think that I would like to use this system frequently**



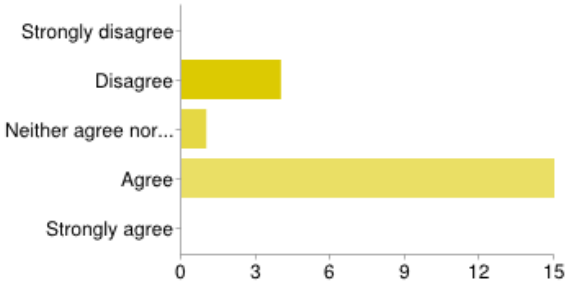

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 13 | 65% |
| Strongly agree | 1 | 5% |

**System usability scale (SUS) - I found the system unnecessarily complex**



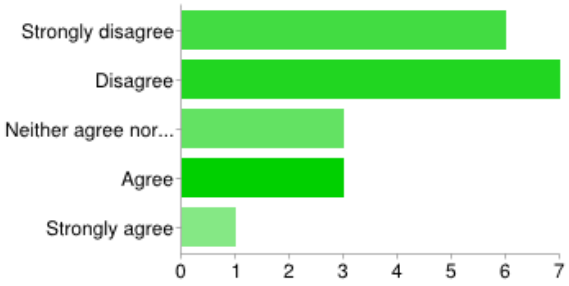

| | | |
|---|---|---|
| Strongly disagree | 3 | 15% |
| Disagree | 9 | 45% |
| Neither agree nor disagree | 7 | 35% |
| Agree | 1 | 5% |
| Strongly agree | 0 | 0% |

**System usability scale (SUS) - I thought the system was easy to use**



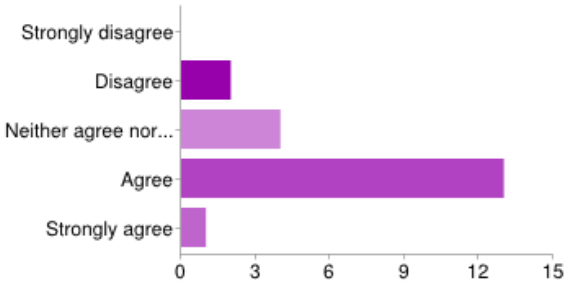

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 4 | 20% |
| Neither agree nor disagree | 1 | 5% |
| Agree | 15 | 75% |
| Strongly agree | 0 | 0% |

**System usability scale (SUS) - I think that I would need the support of a technical person to be able to use this system**



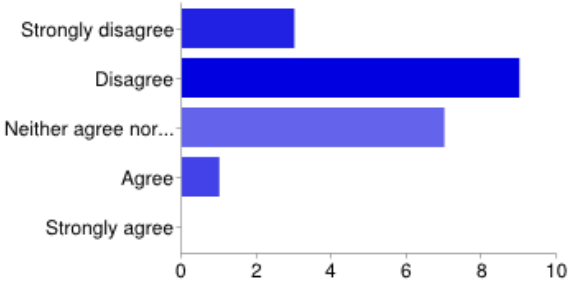

| | | |
|---|---|---|
| Strongly disagree | 6 | 30% |
| Disagree | 7 | 35% |
| Neither agree nor disagree | 3 | 15% |
| Agree | 3 | 15% |
| Strongly agree | 1 | 5% |

**System usability scale (SUS) - I found the various functions in this system were well integrated**



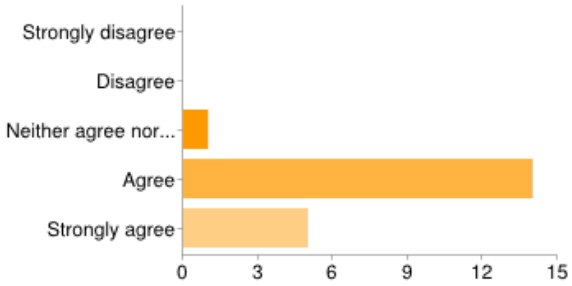

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 2 | 10% |
| Neither agree nor disagree | 4 | 20% |
| Agree | 13 | 65% |
| Strongly agree | 1 | 5% |

**System usability scale (SUS) - I thought there was too much inconsistency in this system**



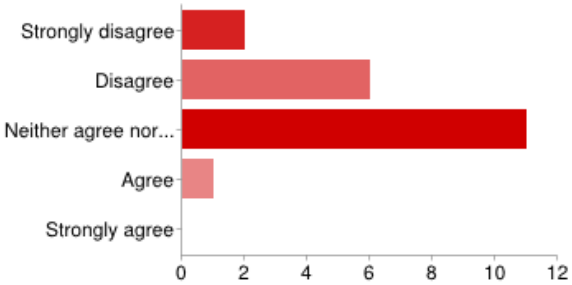

| | | |
|---|---|---|
| Strongly disagree | 3 | 15% |
| Disagree | 9 | 45% |
| Neither agree nor disagree | 7 | 35% |
| Agree | 1 | 5% |
| Strongly agree | 0 | 0% |

**System usability scale (SUS) - I would imagine that most people would learn to use this system very quickly**



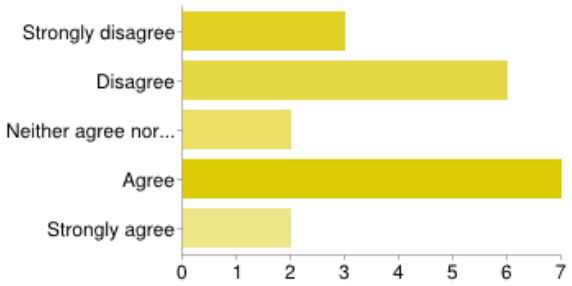

| | | |
|---|---|---|
| Strongly disagree | 0 | 0% |
| Disagree | 0 | 0% |
| Neither agree nor disagree | 1 | 5% |
| Agree | 14 | 70% |
| Strongly agree | 5 | 25% |

**System usability scale (SUS) - I found the system very cumbersome to use**



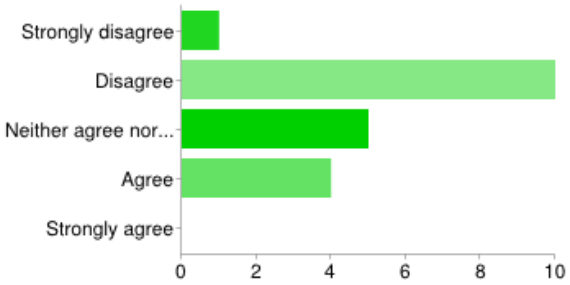

| | | |
|---|---|---|
| Strongly disagree | 2 | 10% |
| Disagree | 6 | 30% |
| Neither agree nor disagree | 11 | 55% |
| Agree | 1 | 5% |
| Strongly agree | 0 | 0% |

**System usability scale (SUS) - I felt very confident using the system**




| | | |
|---|---|---|
| Strongly disagree | 3 | 15% |
| Disagree | 6 | 30% |
| Neither agree nor disagree | 2 | 10% |
| Agree | 7 | 35% |
| Strongly agree | 2 | 10% |

**System usability scale (SUS) - I needed to learn a lot of things before I could get going with this system**




| | | |
|---|---|---|
| Strongly disagree | **1** | 5% |
| Disagree | **10** | 50% |
| Neither agree nor disagree | **5** | 25% |
| Agree | **4** | 20% |
| Strongly agree | **0** | 0% |

# Appendix D

# Questions from the quiz

**What causes oil quality to decrease?**

- ○ Oil being kept in the separator too long
- ○ Too high water level in first separator tank
- ○ Water level in separator too low

**What causes gas quality to decrease?**

- ○ Too high gas pressure
- ○ Too low gas pressure
- ○ Too much fluid in the separator tank

**What causes water quality to decrease?**

- ○ Too high gas pressure
- ○ Water flowing over into the oil tank
- ○ Releasing too much water

**It is ideal to keep the gas pressure below**

- ○ 90
- ○ 30
- ○ 10

**At what pressure level does the safety valve release gas?**

- ○ 20
- ○ 80
- ○ 60

**Closing a valve**

- ○ Increases the gas pressure
- ○ Does not affect the gas pressure
- ○ Decreases the gas pressure

**What happens when the water level gets too high?**

- ○ Water flows into the oil tank
- ○ Nothing
- ○ The gas pressure drops

**What is the purpose of the prosess?**

- ○ Separate oil and gas from water
- ○ Separate water from gas
- ○ Separate oil from water

**Opening the oil outlet affects the water level**

- ○ True
- ○ False

# Appendix E

# Questions from the interview

**Question 1:** Do you feel that you understood the separation process better because of the training given (both verbal and the tutorial)? Why, Why not? Which method was most effective?

**Question 2:** Do you feel that you now understand the separation process better after finishing this experiment? Why, why not?

**Question 3:** Do you think gamification was distracting? Why, why not? Follow up: In what way was it distracting?

**Question 4:** Do you feel that you were in more control with gamification? Why, why not?

**Question 5:** Did you understand the relationship between the graphs in the separators? Follow up: What was difficult to understand?

**Question 6:** Positive or negative things you want to highlight about the system (with gamification)?

**Question 7:** If you could do any changes to the user interface, what would they be?

**Question 8:** What did you think of the visual representation?

**Question 9:** If you could do any changes to the game mechanics / game elements, what would they be? Why?

**Question 10:** Do you feel that your skills was improved because of gamification? Why, why not? Follow up: How was skills improved? / Why do you think that your skills was not improved by gamification?

**Question 11:** What advantages are there in having gamification?

**Question 12:** What advantages are there in not having gamification?