World of Workraft: a step towards the gamification of industrial control systems for future operators

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World of Workcraft: hur gamification av industriella kontrollsystem underlättar för framtida operatörer

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ABSTRACT
Industrial control systems (ICSs) are software systems that allow operators to remotely control entire industrial processes. This activity is usually performed within particular spaces located inside the facilities: control rooms. While the operators’ job is extremely important, it is often regarded as boring and dull; due to the passive nature of the job, the operators often feel unengaged. Industrial stakeholders are concerned about the next generation of operators, due to their different requirements regarding softwares and engagement. In fact, they would not be eager to work with the current ICSs. However, gamification — the design practice about using game design elements in contexts unrelated to games — has potential to contribute in addressing the problem. Implementing gamification within ICSs could make the future operators’ job more fun, appealing, and engaging, providing an overall better user-experience (UX). This research is a step towards achieving an effective gamification of ICSs; it consists of an exploratory study aimed to understand what gamification approaches are more suitable for the industrial context and the target user group. This research adopted an user-centred design approach, starting with extensive user studies on control rooms and the future operators; followed by a design and prototyping phase, and finally a user evaluation involving quantitative and qualitative investigations. This paper ultimately provides a series of design implications and insights for the design of gamified ICS.

Author Keywords
Gamification; Game Design; User Experience; Industry; Control Rooms; Industrial Control Systems; Future Operators.

INTRODUCTION
Gamification is a relatively novel design practice that consists of introducing elements from game design in contexts unrelated to gaming. Its purpose is making the UX [24] more playful and consequently improving the effectiveness of the design intentions (e.g. learning performance, work engagement, customer retention, respectively depending on the context).

Due to the novelty of this design practice, the precise definition of gamification is still debated. Deterding et al. provided one of the most used and cited ones, defining gamification as "the use of game design elements in non-game contexts" [6]. In the past few years gamification was involved in several areas of interests related to both academia and business, such as e-learning, health & wellbeing, and marketing [33]. However, there are extremely few gamification applications within industry, probably due to the traditionally conservative mindset of the related stakeholders. As learned from this research’s user studies, only very recently R&D departments of several industrial related companies are starting to focus on gamification, since they believe that various areas within the industrial context could benefit from this design technique. Among the several possible areas to gamify, there is one that has a particular potential: industrial control systems (ICSs). ICSs are particular softwares that allow the users to visualise and operate whole industrial production processes remotely. The computers running these softwares are usually placed in particular spaces within the industrial facilities: control rooms. Operators make use of ICSs to keep the production going and monitor any malfunction or alarm. According to this research’s user studies, operators’ job is often regarded to be boring and dull; they have to sit in front of the computers even if everything is going well, without anything to do for several hours. Operators usually cope with the boredom by using social media, browsing the web, or socialising with their colleagues. By doing this, the operators become distracted and unengaged with the work.

Moreover, the industrial stakeholders are preoccupied about the generational change that will happen in the next few years. They believe that the new generation of operators
(expected to be hired in the next 5/10 years) will not be eager to work with the current versions of ICSs. This is due to the different requirements about technology usage and engagement between the new and old generations of operators.

This scenario could clearly cause shortages of personnel within industries. Industrial stakeholders believe that implementing gamification within ICSs could contribute to provide a sustainable solution to this issue, improving the UX of operators (making the job more appealing and engaging) and consequently meet the requirements of the new generations.

This research is focused on gamification solutions for future industrial scenarios. For this reason, the study is not considering current operators, but only the future generation of operators, regarded to be the current students of technical/industrial high-schools. This research project was conducted at and in collaboration with ABB Corporate Research, and therefore is focusing on the company’s ICS: 800xA (Figure 1) [41]. Nevertheless, the results of the research are generalisable to the majority of ICSs.

Research Question
The purpose of this research project is to explore how gamification can be implemented within ICSs in order to foster engagement and appeal in the context of future scenarios. The goal was to understand what game design elements should be used in the design of an effective gamified implementation. However, it’s important to note that this research do not focus on providing an actual gamified solution for ICSs; conversely its purpose is to explore the usage of various game design elements and test which ones are more engaging and appealing. The research question is formulated as follows:

- What game design elements would better foster engagement and appeal in a gamified ICS, according to the future operators?

In order to achieve this, multiple user studies were conducted, respectively aimed to understand the current situation in control rooms, the requirements and actual implementation of the ICSs, and most importantly the requirements of the future operators. Afterwards, a series of design concepts and respective mid-fidelity prototypes were presented, designed according to the results of the user studies in combination with a game design theoretical framework. Finally, the prototypes were evaluated with the future operators in order to measure the engagement and appeal. This study ultimately attempts to provide an answer to the research question, and presents additional insights and implications for the design of gamified ICSs.

Scope of the Research
As mentioned, this research does not aim to provide a gamification solution to the engagement and appeal problems within ICSs. Therefore, the various issues related to the actual gamification solution are not discussed in this dissertation. For instance, whether gamification is going to be effective and to what extent is going to solve the engagement and appeal issues is to be considered outside of the scope of this research. In fact, these matters are strongly dependant to the design of a complete gamification approach — something that is not discussed within this project. While the suitability of gamification within the ICSs context is widely discussed in the background section and supported by the user studies, this research does not aim to prove that gamification is the best design technique to address the engagement and appeal problems.

The design of ICSs is performed according to several design principles, in order to assure the effectiveness and minimise human errors. These guidelines are to be considered outside the scope of this research; mainly due to the explorative nature of this study, together with the use of prototypes mostly functional to the discussion with the users and the consequential generation of design implications. While maintaining the consistency with the ICSs design guidelines would be extremely important (and challenging), it is an issue that would need to be faced while designing a complete gamification approach, therefore in the future phases of this project.

BACKGROUND
The gamification phenomenon started gaining awareness around 2010, with the spread of the first gamified applications — such as Foursquare [11]. From that moment, gamification grew in popularity, getting the attention of the business environment. In fact, several companies — from corporations to startups — implemented it in their services and processes, such as Volkswagen’s TheFunTheory project [36] or Nike’s Nike+ [23]. MarketsAndMarkets estimates a massive growth of the gamification industry, predicted to be worth 11 billion USD by 2020 [12].

Gamification spread in various areas, especially in IT services, marketing, consulting, finance, and education [33]. Gamification of work processes (the most relevant for the scope of this project) is sensibly less common than the previous areas. Reeves and Read argued that working and playing are extremely similar activities despite they are often regarded as opposite [28]. To support their point, they identified 40 strong similarities between working activities and playing activities. This argument is supported also by the research of Nick Yee regarding players’ behaviours in the context of Massive Multiplayer Online games (MMOs) [39]. The study shows how these kind of games often implement work-like dynamics, and sometimes are even negatively perceived as “work” by the players. The solid mapping between working and playing practices suggests that gamification would be an appropriate technique for the design of applications and services in the area of working processes.

Defining Gamification
Academia is still currently attempting to provide a solid definition to gamification. The above mentioned definition formulated by Deterding et al. was criticised by Houtari and Hamari [15]. They described gamification as a holistic concept, related to the overall UX and the users’ subjective values. Therefore they argued Deterding’s approach to be...
Gamification in Industry

While gamification is implemented in various areas, there are almost no examples of gamification applied to industrial contexts. The reason might be that industry is in general a very conservative environment, rarely eager to embrace novel technologies. Nevertheless, considering the mapping between working and playing mentioned above, it’s clear that industry would benefit from implementing gamification. While this is very promising, there is almost no academic research conducted within this area of interest. Korn et al. [16,17,18,19] conducted various studies about gamified industrial production, focusing — however — on elders and mentally impaired people. Aside the works of Korn there is no previous literature about gamification within industrial contexts [17]. Siemens recently developed PlantVille [27], a manufacturing simulator allowing players to manage an industrial plant. The goal of this project was to engage the employees and help them understand the working environment. While this is a very inspiring example on how industry could benefit from video-games (and it’s often cited by researchers as gamification), PlantVille has to be actually considered as a serious game. Siemens’ project is in fact an actual simulator game, not an application implementing game design elements.

Ethics in Gamification

The vast majority of gamified applications and services are implementing the common game mechanic of “Points, Badges & Leaderboards” (PBLs) [13]. This mechanic makes use of points (or other kind of virtual currency) to reward the users for completing some tasks or acting in particular ways, badges to state the completion of achievements, and leaderboards to encourage competition between users or groups of users. While this game mechanic is extremely common within gamification, it has been strongly criticised, especially by game designers. The designer Margaret Robertson claimed the current implementation of gamification (implementing PBLs) is “taking the thing that is least essential to games and representing it as the core of the experience” [29]. Designers argue that the core part of games is the content, namely the components related to storytelling, metaphors, settings, and the learning experience [4]. On the other hand, game mechanics such as PBLs should only be complements to enhance the real game content [4]. Designer and scholar Ian Bogost proposed “exploitationware” as an alternative name for PBLs gamification, due to the practice of “deceiving” the users and making them act in favour of the companies without getting any real benefits [2]. A famous example of this phenomenon is the Disney World’s “electronic whip” case, described by the journalist Steve Lopez [21]. The working performances of the employees were tracked and displayed on a leaderboard, pushing them in a very stressful competition, instilling the constant fear of losing the job.

This kind of gamification is not only unrelated to the valuable characteristics of games, but it also often used for mere monetary gain, without providing benefits to the users; breaking the win-win relationship between companies and customers that should characterise gamification practices. This controversy is gaining more awareness among professionals and users. Jakob Skjerning developed ProgressWar, a parody web video-game to satirically address the issue [34]. In ProgressWar the player just have to continuously press a button to complete progressive “missions” and consequentially gaining more experience points. Ian Bogost developed Cow-Clicker [3], a browser game where the players have to click on pictures of cows to earn bonus and complete achievement. These games are a clear critique to the PBLs oriented games and gamified applications.

The raising popularity of this point of view among designers, scholars, and users suggests that a more ethical approach to gamification has to be adopted in order to keep this practice sustainable. Sebastian Deterding, in his article about eudaimonic design [5], proposed a series of design guidelines to rethink gamification in an ethical prospective and “rescue it from gamifiers”. This view is supported also by the empirical study conducted by Shahri et al, which proved the crucial importance of ethical issues in gamification (with a particular focus on enterprise gamification). The researchers claimed that a poorly designed gamification approach would not only be ineffective, but could also provide severe negative effects [32].

Content-Oriented Gamification

As mentioned, implementing gamification setting with focus on the game content rather than the mechanics is
regarded to be a more sustainable practice [4]. Content-Oriented Gamification is the definition that is proposed in this research project to identify the approaches to gamification opposite to PBLs, setting the core of the experience on game content instead of game mechanics.

This is not common within gamification, but there are few examples [13]. Chore Wars is a gamified application that aims to encourage groups of people to do house chores [7]. It makes use of a strong fantasy metaphor to represent the system, in which every user has an avatar that improves as he or she complete real life tasks such as taking out the garbage or cleaning the kitchen. Chore Wars definitely makes use of PBLs mechanics but the core of the experience is still the content. In their research, Reeves and Read claim that graphically representing virtual environments as a 3D virtual spaces is beneficial to the users, helping them to better understand and remember its structure [28]. The researchers also point that users’ self-representation through avatars is a crucial aspect of gamification. These facts suggest that a game content-oriented approach to gamification would be a viable and sustainable alternative to PBLs. It is important to note that the content-oriented approach does not necessarily exclude game mechanics, it just keep the focus of the experience on the content.

**Game Design Core Elements**

The design phase of this research project is mainly based on Jesse Schell’s theoretical framework about the elements of game design. In his dissertation about the art of game design, Schell identified the four core elements of game design: mechanics, aesthetics, storytelling, and technology [31]. The mechanics elements consists of the series of rules and procedures that characterise a game, defining what in game design is called gameplay [31]. Aesthetics is is about how a game looks and feels [31]. The storytelling element is defined as the sequence of events that unfolds in a game [31]. The technology element represents how a game is implemented, involving technological and interaction design aspects [31]. According to Schell, all games should implement these four categories. However, in many games, the focus is set on one or two particular elements. This research project used this theoretical framework as a base for the concept design phase.

**METHODOLOGY**

The methodology used for the whole project is the user-centred design (or human-centred design, or UCD) approach [22]. This methodology features the iterations of a four step cycle composed by: understanding and specifying the context of use, specifying the user and organisational requirements, producing design solutions, and evaluating the design against the requirements [22]. According to Maguire, applying UCD to a design process would contribute to improve the usability and user acceptance, and would foster a better UX [22]. It was decided to apply this methodology because its purposes match with this research’s objectives.

This particular research project features the first iteration of the UCD process, going through the four phases described above one single time. In order to achieve the first phase, a user study within industrial contexts was performed, featuring observations and interviews with operators and managers. The second phase was about specifying the user requirements. In order to achieve this, a quantitative investigation aimed to getting a better understanding of the target user group (future operators) was conducted. This phase consisted of an online questionnaire focused on the users’ preferences and habits regarding video-games. The third phase was about the creation of three design concepts and three respective mid-fidelity prototypes. This phase was mainly based on the results of the user studies as well as on a Schell’s game design theoretical framework [31]. The final evaluation phase started with a brief pilot study to validate the design concepts and prototypes, and finished with the user evaluation. The final evaluation involved ten technical high-school students, who interacted with the prototypes and provided qualitative and quantitative data as feedback.

After conducting the four phases of the user-centred design process the data was analysed and the results were discussed.

All the various phases of this research are explained in-depth in the following sections.

**USER STUDIES**

In this section, the first two phases of the user-centred design process are presented: the user study concerning the context of use, and the ethnographic investigation on the target user group.

**Current Context User Study**

The first step was to gather information about the current scenario of use of ICSs. This was achieved by visiting two actual control rooms in two different industrial facilities: Stora Enso paper mill, and Sandvik steel factory, both located in the area between Sandviken and Gävle (Sweden). Visiting each factory involved a preliminary tour around the facility, a visit in the control room, where it was possible to briefly interview the operators, and finally an interview with a mixed group of employees and managers. The goal of this user study was getting an in-depth understanding of the current usage behaviours and scenarios of 800xA, and the dynamics within control rooms.

The most crucial part of this phase was the control room visit, where it was possible to observe the operators performing routine tasks. According to the observations, the operators seemed bored and sometimes “pretending to work”, probably due to the presence of managers and external stakeholders in the area. During the visits it was also possible to witness the ways operators cope with boredom. There were extremely frequent social interactions between colleagues and several coffee breaks have been observed. During the meetings it was learned that the industries are aware of the boredom problem, they even mentioned control rooms as the “rooms of boredom”. However, it is very likely that the employees were not eager...
to talk in-depth about this issue due to the pressure of being
in presence of their managers and other industrial
stakeholders (such as ABB).

From the meetings emerged a problem regarding the lack of
pro-active behaviours of the employees. Operators, in fact,
are usually very passive about what is happening in the
factory, and they usually wait for the alarms to signal the
problems instead of fixing them before they occur. The
managers want to address this problem, in order to optimise
the production process. Another problem that they face is
the generational change. The current generation of
operators will soon retire, and the industry is experiencing
difficulties in replacing them. Since the operators’ job is
commonly regarded as boring and dull, it is not appealing
for the new generations. Moreover, the young employees
regard their job as boring and meaningless, they do not get
any professional satisfaction whatsoever, conversely, they
just get their work done to receive the wage, and constantly
looking forward finishing their shift.

From the outcomes of the user studies it was possible to
extrapolate some useful implications for the design phase.
The problem of boredom is mainly caused by the lack of
interactions with the system, and — to an extent — by the
repetitive nature of the tasks.

The gamification approach should focus on fostering the
user engagement. Other issues like performances or
learning are not regarded as a crucial problem, therefore
those are to be considered outside the scope of this research
project. On the other hand, encouraging pro-active
behaviours would be also an important requirement for the
gamification approach.

Replacing the operators that retire is also a sensible issue,
since the job is not very appealing to new generations.
Therefore the design of a gamification approach should also
focus on the perceived appeal of the future users for the
system.

A downside of this user study is indeed the small amount of
interviewees. It is extremely difficult to get in contact with
industrial employees and stakeholders, who have very
limited time to dedicate to the project, and are not
necessarily interested in participating. Another limitation
that might have affected the user studies is the employees’
pressure. As mentioned, the presence of their employer and
the relatively formal setting of the interviews might have
affected the informations they shared, and the way they
behaved.

Future Operators User Study
As mentioned, the project is focusing on future users;
according to the interviewed experts, the future operators
have sensibly different requirements compared to the
current operators, especially regarding the gamification
approach and game technologies in general. For this reason
it was required to get a better understanding of the future
users, that — as said — are regarded to be the current
students of technical/industrial high-schools. In order to
achieve this, a quantitative investigation was performed,
aimed to learn the behaviours and habits of the students in
the context of game and video-games.

An online questionnaire was created, in order to investigate
the following aspects:
• Students’ video-game behaviours. What is their view on
video-games? How much they make use of video-games?
• Students’ video-game preferences. What games do they
like to play? What games are they currently playing? What
games genres do they prefer? Which genres would
fit better the gamification approach according to them?
• Students’ player types. What is their video-game player
type, based on the Bartle’s Model [1]?

The online questionnaire was submitted to students of
technical/industrial high-schools. Two institutes agreed to
participate to the study: the ABB Industrygymnasium in
Västerås (Sweden), and the I.T.I.S. Industrial Technical
Institute in Bassano Del Grappa (Italy). The study involved
95 participants, featuring 89% of Italian students, and 11%
Swedish students. The unequal distribution is due to the
different organisational approaches adopted by the
respective institutes. While in some circumstances this
might be considered as a bias, in the case of this research
project it can be ignored. In fact, the students belong to the
same user group (age and background), and — as European
citizens — the cultural background is not to be considered
very different. Moreover, the globalised nature of video-
games contributes to level the cultural differences within
this particular context.

Since the goal of this questionnaire was to get users’
requirements and insights to facilitate the design phase,
reporting the statistical analysis of the data on this paper
would be unnecessary. Assessing the statistical significance
of the results is as well outside the scope of this research
project.

Outcomes of the Questionnaire
The first section of the questionnaire was about the
students’ behaviour and habits regarding video-games. It
was interesting to note that the vast majority of the users are
habitual video-gamer, in which the 79% claimed to play “a
lot”; 12% of the users said they are not huge video-game
fan but they are still playing sometimes, while only the
1,5% claimed they dislike video-games and almost never
play them. The 63% of the users spend more than 1 hour
every day playing video-games, 30% more than 2, and 8%
more than 4. There is also a 10% claiming to play less than
30 minutes per day. The 53% of the users consume from 1
to 3 different video-games per month, and interestingly
there is a 10% consuming more than 8 games per month.

The second section of the questionnaire focused on the
students’ preferences in terms of video-games’ genres. The
users rated on a scale from 1 to 7 all the major game genres
(Action, Role-Play-Games or RPGs, Real-Time-Strategy or
RTS, Shooters, Sports, Simulators, and Puzzle), with the
additional possibility to add others that weren’t in the list.
The most appreciated genres are: Action, RPGs, RTS, and
Shooters; while Sports, Simulators, and Puzzle got sensibly lower ratings.

The students provided various lists of video-game titles, including their favourites, the most recently played, and the ones they regard as the most suitable for a gamification context. The results are extremely diverse, therefore impossible to list in this report. Nevertheless it was possible to observe a pattern between the lists and the favourite genres. The listed video-games — in fact — tend to belong to categories previously mentioned as more preferred.

The final section of the questionnaire was about the students’ player type. According to Richard Bartle every video-game player is characterised by four different traits: Achiever, Explorer, Killer, or Socialiser [1]. Players do not necessarily have to belong to a single category, but in general they have one or two predominant traits. Every player type has different design implications, therefore knowing if there is a predominant type (or even multiple types) within the user group would strongly affect the design. In order to achieve this, a Bartle’s Player Type questionnaire was embedded inside the online questionnaire. The outcomes showed that the distribution of the traits was extremely equal, meaning that there was no predominant trait among the target users. While this is quite interesting to acknowledge, it did not affect the design and therefore is irrelevant for the scope of this project.

DESIGN

The design phase aims to create three different gamification concepts. The concepts were based on the data gathered during the user studies, and on Jesse Schell’s framework about game design. The three prototypes are based on three elements of Schell’s framework: mechanics, storytelling, and aesthetics. It was decided to keep the technology element outside the scope of the research; the project is about 800xA and therefore there is already a set of technological requirements that are immutable.

The design of the three concepts took into account also the gamification ethics discussed in the background section. The various concepts were strongly affected by the content-oriented gamification, setting the focus mainly on game content instead of game mechanics, even though one concept implements game mechanics as well.

According to the user studies, the majority of the target users are hardcore-gamers (people that have video-gaming as primary hobby), who spend a relatively large amount of time playing every day. For these reasons, it can be inferred that the users would appreciate more a gamification approach that strongly tends to actual video-games, instead of an approach only mildly related to them.

From the user studies it was possible to extrapolate two other design requirements. Firstly, the importance of the designs’ appeal: due to the generational change problem described above, it is essential to make the concept appealing to the target user group. This is achieved by implementing a strong metaphor, representing the industrial setting as a medieval village. Every element of the industrial production is mapped to the metaphor, for example a kneader becomes a medieval windmill. The medieval village is a clear connection with the RTS and Action-RPG video-game genres, rated by the target users as their favourites. The second requirement is about what aspects of 800xA to gamify. According to the data gathered during the user studies it would be insufficient to only gamify the existing functions, since the “boredom” problem resides also in the lack of interactions between the operators and the system. It is required to add a layer of gamified affordances on the top of the existing system, adding more possible actions to the regular workflow.

The design process involved various iterations of brainstorming and concepts creation. Several low-fidelity prototypes (such as sketches and drawings) were created during the process before getting to the final design and relative high-fidelity prototypes. However, for the scope of this project it would be unnecessary to show the various design activities, as the actual designs are only slightly relevant to the goal of the research (the focus is in fact set on the various game design elements and game content).

The Industrial configuration

800xA is an extremely complicated software, implementing hundreds of features. Every industry is implementing a completely different configuration of 800xA, in order to have only the required features and interface set-up. For example, the 800xA configuration used in Stora Enso is extremely different from the one used in Sandvik, and so are the tasks performed on these softwares. To create a prototype that aims to simulate 800xA is required to decide on a pre-defined industrial setting. This study will replicate a setting of a food production industry, since the process is generally more simple and intuitive to understand than other kind of industries. In order to design and develop a simulator of this industrial environment it was necessary to get a better understanding of the process and the tasks performed by the operators. To achieve this, in-depth interviews with food industries stakeholders in Italy and Morocco were conducted. The interviewees explained how the production works, and how it is controlled by the softwares. Moreover they provided a list of the 10 most common actions that operators have to perform during their working routines. The tasks are mostly related to visualising alarms, editing values to correct the production flow, and checking the status of various elements. All the design
concepts are based on the industrial configuration provided by the experts (shown in Figure 2). This allowed to create the concepts within a realistic scenario.

**The Three Design Concepts**
The three design concepts: The Good, The Fancy, and The Teller are hereafter presented. Respectively implementing the mechanics, aesthetics, and storytelling elements of game design.

**Mechanics Concept: “The Good”**
The Good is implementing the mechanics element. The representation of the industrial concept is extremely low-fidelity in this concept (while the metaphorical aspect is still strong). The main feature of the concept is the avatar representing the user as a medieval character (in this case a squire). The avatar can be improved by acquiring new gear from a shop (the user can buy a shield or a helmet), spending a virtual currency that is earned by performing tasks through the system. The users are also able to visualise their co-workers’ avatars, and check their progress. It is important to note that while this concept is implementing various game mechanics elements (also related to the PBLs gamification), the focus of the design is still on game content. The virtual currency — in fact — is not used as the core of the experience, but just as an element to enhance it.

**Aesthetics Concept: “The Fancy”**
The Fancy is implementing the aesthetic element. This concept features a strong 3D graphical component, and the users are able to turn their viewpoint around in order to fully observe the surrounding.

Even though the graphic is extremely different from the other concepts, the mapping of the medieval village on the industrial setting is performed in an analogue way. While thanks to the 3D high-fidelity graphics this concept provide the look and feel of a real video-game, it doesn’t feature any additional interactivity compared to the non-gamified version (aside the possibility of navigating the 3D environment).

**StoryTelling Concept: “The Teller”**
The Teller is implementing the storytelling element, defined as the sequence of events that unfolds in a game [31]. This concept features a very low-fidelity graphic, similar to the design of The Good. The storytelling is implemented through a series of overlay characters that appears when events occur, communicating with the users with comic-like text boxes. The concept implements a very small story that features a villager asking help to the user in order to solve a problem within the industrial configuration (described by the villager as a building on fire). After fixing the problem, the user will encounter the queen of the village and briefly interacting with her regarding what would be the user’s reward (the possibilities are: nothing, a kiss, or money). While the story is short and very low-fidelity (compared to a regular video-game), it implements the essential elements like text-based interaction with different characters and the possibility of giving multiple answers (and consequently receiving different feedbacks).

**Prototyping**
This last phase of the design process aim to create of three medium-fidelity prototypes respectively representing the three design concepts previously presented. The prototypes allow the users to simulate the working experience with the gamified versions of 800xA. The interfaces configurations were based on the pre-defined food industry setting discussed above. Obviously the prototypes do not implement all the functionalities of the original software,
but only the features required for the completion of the most common routine tasks. The developing of such system relied completely on the information gathered during the industrial technologies user studies.

In addition to the three gamified prototypes, also a “neutral” version has been developed (Figure 6). This version does not implement any gamification elements. It is useful only for purposes related to the final evaluation. This matter is discussed in depth below.

![Figure 6. Screenshot of the “neutral” version](image)

All the prototypes were implemented using Unity3D, the well known game engine. They are completely stand-alone applications, not linked in anyway to the original software. Therefore all the interactions and feedbacks are simulated. Screenshots of the three prototypes are shown in figures 3, 4 and 5.

PILOT STUDY
This pilot study aims to briefly evaluate the design concepts before the final experiment. It was necessary to assess whether the design concepts effectively represent Schell’s game design elements. In fact, while the design process followed a pre-defined methodology, and the main design choices were made according to the data gathered from the user studies, there was still the possibility of biases caused by the few subjective design choices that had to be made during the process.

This pilot study involved eight test users not belonging to the target user group. The participants were graduate students of various technical disciplines, not educated in gamification or game design. This choice was made due to the difficulty of involving the actual target user group. Nevertheless, considering the goal of the pilot study, this shouldn’t be considered as a significant bias, especially because of the similarities between the two user groups: similar age, similar background, etc.

The pilot study was conducted individually; each participant got a oral explanation on the background of the project relevant to the pilot study, and an overview of Schell’s game design elements. Afterwards the participants got an overview on the design concepts and their features. Finally the participants had to correlate the concepts with the corresponding game design elements. The test was conducted in a very informal way, and in different settings (only a laptop, pen, and papers were required). In order to let the participants respond, a paper based quiz was created, they had to draw a line to link the screenshots of the prototypes to the respective game design elements. The template of the quiz can be found in Appendix 3.

The outcomes of the test were extremely positive. All of the participants were able to correctly correlate the three concepts to the respective game design elements. After taking the test, a participant claimed: “this was pretty straightforward”, another said: “already done? It was the easiest test ever?”. No participant mentioned anything about the test being challenging. These outcomes prove that the concepts are representative of the game design elements, and the final evaluation wasn’t affected by design biases.

USER EVALUATION
The final user evaluation aimed to understand which game design elements resulted to be more appealing and engaging to the target user group. The experiment was structured as a within-subject evaluation, with both qualitative and quantitative investigations. The study involved ten participants, all belonging to the target user group: seven Italian students from I.T.I.S. E. Fermi, and three Swedish students from ABBIndustrygymnasium. For the same reasons discussed in the user studies section, the unequal distribution of nationalities within the group of participants is not to be considered as a significant bias in the context of this research. The participants were recruited through a convenience sampling technique [37], contacting all the students that participated in the previous user study (afterwards, also a Snowball sampling [37] was tried, but turned out to be ineffective). Ten students voluntarily decided to participate (coffee and cake were offered as compensation); the amount of participants was limited, however — according to Tullis and Albert — within-subject experiments do not need large samples of users [37].

The participants took part in the experiment individually; the first step was explaining to them the context of the research project, including information about the background, the problem within control rooms, and how gamification would solve it. Secondly, they received an explanation about the food industry environment, in order to provide them a brief overview on the workflow and therefore facilitate their tasks during the actual evaluation. Afterwards the participants had to interact with the neutral version of the prototype (without gamification) and complete a list of pre-made tasks; the purpose was to teach them how to interact with the prototypes before-hand, in order to avoid possible learning biases while interacting with the gamified prototypes. The next step was to let the participants try the three gamified prototypes. Counterbalancing was applied every time to the order of the three prototypes, in order to avoid any possible learning bias [37]. For each of the prototypes the participants had to follow pre-defined instructions. They had to complete particular tasks that match with the actual routine actions that the operators have to perform in the real industrial context. The choice of using pre-defined instructions during
the evaluation is done in order to structure the participants’ interaction with the system. While this was important in order to assure the participants interacted properly with the prototypes, describing the various tasks in depth is outside the scope of this research. However, the complete lists of tasks (one for each prototype) is included in the Appendix 4.

After interacting with each prototype the participants had to fill the User Engagement Survey. This survey was designed and evaluated by O’Brien and Toms [25] as a tool to measure the perceived user engagement of software usage. The questionnaire measures perceived usability, novelty, aesthetics, felt involvement, and focused attention as perceived by the test users. The various questions were slightly edited in order to fit the experiment context since the original provided by the scholars is designed for the evaluation of web pages (the actual questionnaire can be found in the appendix 1 of this paper). All the questions were posed on a Likert scale from 1 to 7. The results of the quantitative investigation were submitted to a statistical analysis in order to assess their significance. The tool used was the unpaired t-test with 18 degrees of freedom and a confidence interval of 95%. Since the data consist of three distributions (one for each gamified prototype), three t-test were conducted for every question (*The Good* against *The Fancy*, *The Good* against *The Teller*, and *The Teller* against *The Fancy*), in order to be able to analyse the complete spectrum of possibilities.

After interacting with the three gamified prototypes, the participants were involved in a interview in order to gather qualitative feedback about the experiment. The interviews were Semi-Structured [30], thereby not having a strict progression of questions, but only several topics to discuss in an informal way. The interviews aimed to gather insights regarding the perceived engagement, appeal, general UX and other thoughts about the prototypes, in order to integrate the quantitative data.

Due to logistic reasons, the experiment were conducted in several different locations; mainly bars and cafés in Italy and Sweden. In general the settings were very informal, and the users received coffee and cake as compensation for their participation. Since providing an extremely realistic simulation of 800xA was not in the scope of this research project, any possible bias caused by the settings of the experiment should not be considered significant.

**Quantitative Results**

While the amount of participants was very limited, 10 questions out of 16 provided significant results. In this section, an overview of the most relevant and significant results is provided, while the complete analysis of the data can be found in Appendix 2.

*The Fancy* resulted to be significantly more appealing and engaging than the other prototypes. Moreover, the students’ ratings indicate that the time spent on the *The Fancy* “flew away” more than with the other prototypes. *The Fancy* resulted to be significantly more appealing and aesthetically appealing (the latter result was clearly expected). *The Fancy* also triggered more curiosity in the participants. Some other questions provided insignificant results; for example when asked whether the participants would continue using the prototype out of curiosity, there is no difference between the ratings of the three prototypes. Also the questions about the success of the experience and the overall satisfaction of the experience provided insignificant results. There are finally questions that were expected to be insignificant and resulted to be so; the questions about whether the prototypes were confusing, discouraging, and demanding to use, did not provide significant differences, partly confirming the quality of the designs.

According to the results gathered, it would be incorrect to claim that a prototype resulted to be entirely more engaging than the others. However, the majority of the data gathered was useful to integrate the qualitative data and provide a more complete discussion.

**Qualitative Result**

The results from the semi-structured interviews were collected through notes while discussing with the participants. The relevant comments and thoughts gathered during the evaluation are hereafter presented, divided in three subsections, one for each prototype, plus an extra section for general feedback.

It’s important to note that the qualitative results gathered during the experiment were saturated. This means that after ten experiments the insights and comments provided by the participants started to repeat, experiencing a lack of new material during the last experiments. This proves that the amount of participants was enough to fulfil the goals of the investigation [10].

**Feedback on “The Good”**

This prototype was the most criticised by the participants. Six out of ten students were skeptical about the very nature of the gameplay; one claimed: "reminds me too much of FarmVille", in a context where FarmVille is intended as an archetype of PBLs gamification [9]. Others regarded the prototype as slightly boring or dull: "it’s a bit like the same old gamification", recognising in the prototype some well-known gamification patterns.

Three participants regarded the mechanic intriguing, and suggested also other approaches, like letting the operators improve the aspect of the medieval village instead of the avatar. Five of participants suggested a multi-player implementation of the prototype: "that would be the killer-app!". They claimed that being able to interact more with the co-workers would be very interesting, setting up some kind of competition, for example making them able to trade or combat between their villages. While excited about the multi-player, some participants were concerned about the possible negative outcomes of this implementation. Some said: "I’d probably get super-angry with my colleague if he trashes my village to the ground!", and other kinds of unhealthy competition. The solution that three students suggested was to design the multi-player prototype with a co-operative paradigm, or at least with a competition
between groups of operators (like shift teams, or competition between different industries).

**Feedback on “The Teller”**
Four participants appreciated the prototype, while the rest ignored it. The four students claimed to like it very much, suggesting various improvements: “I would like to have a continuous storyline that develops over-time”, or: “I would like to see more characters, maybe one for every element of the interface”. Another raised an interesting point about how the system conveys the notifications to the operators, saying: “I think it’s better to have a character informing you of something happening instead of having an annoying alarm ringing”. However, the remaining six participants did not show interest for this prototype. In general, the interested users regarded themselves as fan of the video-games with a strong storytelling component: “I’m probably the only one that like this... but I’m a huge fan of this kind of games”.

**Feedback on “The Fancy”**
This prototype was the far most appreciated one. Eight participants claimed to be thrilled with the graphics of the interface. These participant said that this one seemed the most professional due to the realisation quality. A student in particular said: “It seems like a real video-game to me!”, even though there is no actual interactivity within the prototype. Six students raised a very interesting point about the importance of graphic realisation, they claimed that they wouldn’t be eager to interact with games (or gamified applications) that don’t implement good graphics (not necessarily state-of-the-art, though). A possible improvement was also suggested by a couple of students: they would like to have the interface more crowded with details: “you know, like ‘Where is Waldo?’ pictures” [38]. The students claimed that they really appreciate the crowded (and possibly slightly interactive) interfaces, taking Blizzard’s Heartstone [14] as a notable example.

**General Feedback**
Three participants raised a concern regarding the metaphor used in the design. While many appreciated the medieval setting, they were concerned about the possibility to apply the same metaphor to other industrial contexts: “It does fit the food industry, but what about an industrial power plant?”. Two students were preoccupied that the cartoonish style of the prototypes (especially The Good and The Teller) would strongly affect how the industrial software is perceived, they claimed that it would look sensibly less serious and that this might have consequences: “I guess that for someone it might be a problem...”. However, six out of ten participants claimed to appreciate the medieval metaphor. It is also worth mentioning that five participants acknowledge the fact that a complete gamification approach should implement all the game design elements, while they understood that the prototypes were just design probes.

**DISCUSSION**
Before discussing the results it is important to specify that the three prototypes were not designed to be complete gamification solutions, but just design probes to support the explorative study and facilitate the gathering of feedback and insights. The prototypes, in fact, were based on the various elements of Schell’s framework, but according to the game designer, all the four elements have to be included when designing a game (with the exception of the technology element, that was skipped for the reasons discussed previously). It can be argued that this same idea applies to gamification; this is proved by the fact that no prototype was perceived as a full gamification approach by the evaluation participants (nor was intended to be one). However, the prototypes were designed to facilitate the evaluation, and make it easier to test and gather insights regarding the specific game design elements.

While not all the questions in the engagement survey provided significant differences between the prototypes, it is observable that The Fancy got the highest ratings in almost all the questionnaire. This data, together with the insights and feedback gathered during the qualitative investigation, strongly suggest that aesthetics would play a crucial role in fostering user engagement in a gamification approach. Moreover, from the qualitative and quantitative data, is possible to safely claim that aesthetics foster significantly more appeal in the gamified context than the other game design elements. As mentioned before, the aesthetic element was already regarded as an essential component of game design, however it resulted to be significantly more important than the other elements. The importance of aesthetics is confirmed by the participants. According to them, the more a gamified application would resemble an actual video-game, the more would be the resulted engagement and appeal. On the other hand, implementing a low-quality graphic, would have negative consequences on these perceived characteristics. This point is particularly interesting to acknowledge, especially in a context in which independent video-games or “indie games” — generally characterised by lower quality graphics — are raising awareness within the video-gaming panorama [8].

Aside understanding what game design element would foster the more engagement and appeal, the data gathered during the study also provided multiple insights and implications for the design of gamified ICSs. Hereafter are presented the points worth discussing.

**The future operators**
During the first phases of this research, an ethnographic study on the target user group was performed. The outcome of this study was the creation of a new “gaming persona”, representing the future operators under the perspective of their habits and preferences regarding video-games. The majority of the participants resulted to be passionate video-games players, sometimes defining themselves **hard-core gamers**. This kind of gamers resulted to have particular preferences regarding video-games genres (Action, RTS, RPGs) that should be taken into account when designing a gamification approach. On the other hand, implementing any reference to **casual games** (simple games designed for occasional players), such as PBLs would be self-defeating (as discussed in depth in the next section).
The shadow of PBLs
As discussed in the background section of this research, the PBLs gamification is regarded to be unethical and generally unsustainable. The design of the various gamification concepts took into account this issue, and even if some PBLs elements (such as points) were included in the design, the focus of the implementation remained on the game content. However, despite keeping the focus on game content, several participants noticed the presence of PBLs elements and did not appreciate them. As mentioned above, they have been reminded of games such as FarmVille, which — as hard-core gamers — they regard as very bad games. For these reasons, the design of a gamified ICS should completely avoid any explicit reference to PBLs gamification; or it should at least implement design (and game design) solutions in order to make the references invisible.

The multi-player paradigm
According to the results of final evaluation, several participants regarded multi-player as an essential feature. They would really appreciate the possibility of interacting with their peers. This requirement relates also to the initial ethnographic study, where several of the games that the students indicated as their favourites involved multi-player in some way. As stated by some participant, implementing multi-player would be the killer application of the gamified solution, with the additional advantage of improving the longevity of the implementation. However, it is important to note that direct competition between operators might have negative consequences, such as fights or disagreements. Therefore, it is suggested to implement a co-operative paradigm instead, making operators play together to achieve common goals.

The metaphorical representation
In order to foster the content-oriented gamification approach, it was chosen to apply a metaphorical representation to the ICS interface, visualising all its components as a medieval village. While the idea was strongly appreciated by the test participants, they raised some concerns. The participants claimed that the medieval metaphor definitely fits the food industry case, but might be confusing when applied to other contexts (for example a nuclear power plant). In order to create an effective and self-explanatory interface it is required to choose carefully the metaphor to apply. While this might be a challenging task, the appreciation shown by the participants suggests that having a metaphorical representation of the interface would be a viable strategy to foster engagement and appeal.

CONCLUSIONS
This project attempted to understand what game design elements foster more engagement and appeal when implemented in a gamified ICS. The ultimate goal of this research was to put the foundations for an effective gamification within the context of ICSs. The results showed that among the Schell’s core elements of game design, aesthetics fosters engagement and appeal the most. Moreover, the large amount of quantitative and qualitative data gathered during the whole research process provided various insights and implications regarding the design of gamified ICSs. Besides the importance of aesthetics mentioned before, it was discussed the risk of using PBLs elements, as well as the benefits of implementing a multi-player paradigm, and the challenge of creating a metaphorical representation of the interface. Additionally, details about the future operators’ personas are presented, as well as few related requirements and design implications. This exploratory study provides information essential to implement gamification within ICSs; the outcomes of the research would be extremely useful for researchers and gamification or UX designers.

Limitations
The methodology chosen for this research resulted to be too extensive, compared to the time given to complete the project (few months). This planning error generated a couple of major limitations. The first resides in the methodology, that had to be modified according to the time restrictions. An example is the number of concepts that it was possible to design and develop. Probably, having a larger number of diverse prototypes would have resulted in a more complete set of design implications and insights. A second major limitation consists of the number of users involved in the final evaluation. Even though ten participants might be considered an adequate amount (especially since the results are mostly scientifically significant), improving the number would have probably provided more and better results. However, the short amount of time given and the difficulty of involving the target user group have to be considered.

Future Work
This research is the first step of a bigger project that aims to provide an actual gamified solution to the control room engagement problem. The data and results gathered during this research create the foundations for the future phases of the project. The next step will be reiterating the user-centred design process, with a particular focus on designing new prototypes that would implement all the game design core elements, thus providing a complete gamified solution. The new design concept would implement all the design implications generated by this study.

ACKNOWLEDGMENT
I would like to thank my supervisors at ABB Elina Vartiainen and Alvaro Aranda for the precious help during the whole process, as well as Susanne Timsjö for the great learning opportunities. Thanks to Vyagandas “Vegas” Simbelis and Mario Romero from KTH for the supervision and good advices. A big thank to Claudio Brazzale from I.T.I.S. E. Fermi, that saved the day during the user studies. Finally thanks to my mother and father who respectively provided essential psychological and technical support.

REFERENCES


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41. 800xA. ABB Group.
Appendix 1: User Engagement Survey

User Engagement Questionnaire

1. User And Mode

2. I was so involved by the prototype that I lost track of time
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

3. The time spent using the prototype just slipped away
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

4. I was really drawn into using the prototype
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

5. I felt involved doing tasks
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

6. I would continue using the prototype out of curiosity
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

7. The prototype incited my curiosity
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

8. I consider my experience with the prototype a success
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

9. My experience did NOT work out the way I had planned
   Mark only one oval.
   1 2 3 4 5 6 7
   Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

10. My experience with the prototype was rewarding
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

11. This prototype is attractive
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

12. This prototype is aesthetically appealing
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

13. I liked the graphics and images used on this prototype
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

14. I found this prototype confusing to use
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

15. I felt discouraged while using this prototype
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

16. The experience with the prototype was demanding
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree

17. I would like to work with a system similar to this prototype
    Mark only one oval.
    1 2 3 4 5 6 7
    Strongly Disagree ○ ○ ○ ○ ○ ○ ○ Strongly Agree
Appendix 2: Statistical Analysis of the Quantitative Data

In the first table are presented the mean and standard deviation of the various questions. In the second table are presented the results of the unpaired t-test (18 degrees of freedom, 95% confidence interval) between the prototypes.

<table>
<thead>
<tr>
<th>Question #</th>
<th>The Good</th>
<th>The Teller</th>
<th>The Fancy</th>
</tr>
</thead>
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<tr>
<td></td>
<td>MEAN</td>
<td>SD</td>
<td>MEAN</td>
</tr>
<tr>
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<td>4</td>
<td>0</td>
<td>4.12</td>
</tr>
<tr>
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<td>4.34</td>
<td>1</td>
<td>4.12</td>
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<td>0.71</td>
<td>4.34</td>
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<td>0.53</td>
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<td>4.78</td>
<td>1.21</td>
<td>4.89</td>
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<td>4.78</td>
<td>1.1</td>
<td>4.45</td>
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<td>8</td>
<td>5.23</td>
<td>0.67</td>
<td>4.89</td>
</tr>
<tr>
<td>9</td>
<td>2.45</td>
<td>0.89</td>
<td>2.45</td>
</tr>
<tr>
<td>10</td>
<td>4.78</td>
<td>0.84</td>
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</tr>
<tr>
<td>11</td>
<td>4.45</td>
<td>0.73</td>
<td>4.56</td>
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<tr>
<td>12</td>
<td>3.78</td>
<td>0.84</td>
<td>4.34</td>
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<tr>
<td>13</td>
<td>4</td>
<td>0.87</td>
<td>4.45</td>
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<td>14</td>
<td>1.89</td>
<td>0.34</td>
<td>2.56</td>
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<tr>
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<td>1.89</td>
<td>0.34</td>
<td>2.23</td>
</tr>
<tr>
<td>16</td>
<td>1.34</td>
<td>0.5</td>
<td>2.12</td>
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<tr>
<td>17</td>
<td>4.67</td>
<td>0.71</td>
<td>5.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>#</th>
<th>The Good / The Teller</th>
<th>The Good / The Fancy</th>
<th>The Fancy / The Teller</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>t = 0.4803  p = 0.6368 not significant</td>
<td>t = 3.0263  p = 0.0073 very significant</td>
<td>t = 1.9995  p = 0.0614 not significant</td>
</tr>
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<td>3</td>
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<td>t = 1.5355  p = 0.0688 not quite significant</td>
<td>t = 2.8305  p = 0.0111 significant</td>
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<td>4</td>
<td>t = 3.1494  p = 0.0055 very significant</td>
<td>t = 9.3616  p = 0.0001 extremely significant</td>
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</tr>
<tr>
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<td>t = 1.7219  p = 0.1022 not significant</td>
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<td>t = 1.8042  p = 0.0800 not significant</td>
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<td>t = 1.2841  p = 0.2154 not significant</td>
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<tr>
<td>8</td>
<td>t = 0.7975  p = 0.4356 not significant</td>
<td>t = 1.6844  p = 0.1134 not significant</td>
<td>t = 1.9386  p = 0.0684 not quite significant</td>
</tr>
<tr>
<td>9</td>
<td>t = 0.0000  p = 1.0000 not significant</td>
<td>t = 0.9947  p = 0.3331 not significant</td>
<td>t = 0.9394  p = 0.3600 not significant</td>
</tr>
<tr>
<td>10</td>
<td>t = 0.6251  p = 0.5397 not significant</td>
<td>t = 1.4643  p = 0.1603 not significant</td>
<td>t = 2.1719  p = 0.0435 significant</td>
</tr>
<tr>
<td>11</td>
<td>t = 0.2417  p = 0.8117 not significant</td>
<td>t = 4.2335  p = 0.0005 extremely significant</td>
<td>t = 2.8606  p = 0.0104 significant</td>
</tr>
<tr>
<td>12</td>
<td>t = 1.4643  p = 0.1603 not significant</td>
<td>t = 6.4171  p = 0.0001 extremely significant</td>
<td>t = 4.7899  p = 0.0001 extremely significant</td>
</tr>
<tr>
<td>13</td>
<td>t = 0.8907  p = 0.3848 not significant</td>
<td>t = 7.6052  p = 0.0001 extremely significant</td>
<td>t = 4.3890  p = 0.0004 extremely significant</td>
</tr>
<tr>
<td>14</td>
<td>t = 0.7100  p = 0.4868 not significant</td>
<td>t = 0.5901  p = 0.5625 not significant</td>
<td>t = 0.9248  p = 0.3673 not significant</td>
</tr>
<tr>
<td>15</td>
<td>t = 0.7463  p = 0.4651 not significant</td>
<td>t = 0.2534  p = 0.8028 not significant</td>
<td>t = 0.3769  p = 0.7108 not significant</td>
</tr>
<tr>
<td>16</td>
<td>t = 1.8072  p = 0.0875 not quite significant</td>
<td>t = 1.2017  p = 0.2450 not significant</td>
<td>t = 0.9780  p = 0.3410 not significant</td>
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<tr>
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<td>t = 2.2750  p = 0.0354 significant</td>
<td>t = 1.1813  p = 0.2528 not significant</td>
</tr>
</tbody>
</table>
Appendix 3: Pilot Study “Quiz”

Link with an arrow the prototype with the corresponding game design element

Your Name:

Mechanics

Aesthetics

Storytelling
Appendix 4: User Evaluation instructions

The instructions to facilitate the interaction with the various prototypes were presented as follows. However, during the actual evaluation the tasks were presented on separated paper sheets (one for each prototype, or stage); while in this document they are jointed for space reasons.

Gamification Experiment!

Stage / Regular Mode

User the regular mode to start the factory production! Complete the following tasks:

1. Set Flour Silos
   Set the source of the flour to be Silos #3

2. Change Pasta Recipe
   In the Recipe Menu, set the recipe for Spaghetti 7-600

3. Activate Motors
   Activate the following motors by clicking on them and switch to “ON”:
   - 25M1
   - 26M1
   - 24M1
   - 28M1
   - 32M1
   - 38M1

   Cheers, the production is now functioning :D

Stage / Game Mechanics Mode

After a while, you need to change the recipe, and make a slightly different kind of pasta. As you complete the required tasks, you gain points to spend to improve your avatar.

1. Deactivate Egg Flow
   Deactivate motor 26M1 to stop the egg flow in the machine.

2. Change Recipe
   Change recipe from the menu, choose Spaghetti 9-800.
3. Resolve Alarm
Enter in the alarm menu and solve the alarm.

Now try to personalise your avatar with the money you earned :)

**Stage / Storytelling Mode**

At some point a problem will arise, the pressure in the Screw is too much! In order to solve the problem you need to do the following tasks:

1. **Raise Water Temperature**
   Enter in the Water Tank menu and raise the temperature by 1 degree (from 25.5 to 26.5).

2. **Raise Water Flow**
   You need to augment the amount of water getting in the Centrifuge. Enter the 25P1 pump menu and change the Hz value to 20.3 (instead of 19.3).

Witness what happens afterwards!

**Stage / Aesthetics Mode**

At a certain point an alarm would trigger because the flour silos is almost finished, you need to change it with a full one!

1. **Switch off Flour Motor**
   Click on the 24M1 Engine and switch it off.

2. **Change Silos**
   Enter in the silos menu and choose a full one instead.

3. **Change**
   Change also the valve value from 20 to 25.

4. **Reactivate Motor**
   Reactivate Flour Motor 24M1.

Well done :D