Kasper Kovanen

Gamification in Human-Centric Operations

Method for Manufacturing Execution Systems

School of Technology and Innovations
Master's thesis in Information Systems

Vaasa 2023

UNIVERSITY OF VAASA
School of Technology and Innovations
Author: Kasper Kovanen
Title of the Thesis: Gamification in Human-Centric Operations : Method for Manufacturing Execution Systems
Degree: Master of Science in Economics and Business Administration
Programme: Information Systems
Supervisor: Teemu Mäenpää, Laura Havinen
Year: 2023 **Pages:** 123

ABSTRACT:

Manual labor tasks can be repetitive and lack feedback, but what if we could add game-like elements to them, or enable gameful experiences? However, gamification, the addition of game-like elements or gameful experiences, can address this issue. Gamification is a growing area of research that has gained attention and yielded results, particularly in education and general business processes. This thesis presents research on how gamification could be applied to a Manufacturing Execution System (MES). The research question is “How should a gamified MES be designed?” The research is commissioned by a company in the manufacturing sector, in co-operation with an international manufacturing company as part of their joint Industry 5.0 initiative.

To begin, research establishes a theoretical background of gamification and its applications in similar manufacturing environments. This thesis presents practices, methods, recommendations, and features for gamification in general, as well as context-specific knowledge. The design science research methodology is used to achieve important outcomes, such as setting the knowledge base, designing and developing the gamification artifact, and demonstrating it through mock-ups. The design and development process is informed by qualitative data gathered through observation and interviews. The data is analyzed to gain knowledge about the context and users. The analysis resulted in nine dimensions of context, a player persona, and emerging knowledge. All these factors inform the design of the artifact, which provides recommendations for how gamification should be designed for MES.

The main result of the research is the method artifact, which consists of actionable guidelines that companies can use to guide their future implementation of a gamified MES. Six design principles summarize the guidelines. The research yielded design principles for feedback on work, competence development, among others. Eleven wireframe mock-ups demonstrate the design principles and illustrate which gamification elements are appropriate for use in a gamified MES.

The research only considers the employee's perspective and does not consider the business needs necessary for further implementation of a gamified MES. Therefore, future research should focus on aligning business needs with identified user needs, evaluating the artifact further, and implementing a gamified MES based on the artifact. Additionally, research should explore how the wider organization, including management, could benefit from a gamified MES. Another area for future research is the integration of a gamified MES with other systems, such as ERP, CRM, HR, or quality assurance systems, to improve feedback.

KEYWORDS: gamification, manufacturing execution systems, human-machine interaction, design science research

VAASAN YLIOPISTO
Tekniikan ja innovaatiojohtamisen akateeminen yksikkö

Tekijä:	Kasper Kovanen
Tutkielman nimi:	Gamification in Human-Centric Operations : Method for Manufacturing Execution Systems
Tutkinto:	Kauppatieteiden maisteri
Oppiaine:	Tietojärjestelmätiede
Työn ohjaaja:	Teemu Mäenpää, Laura Havinen
Valmistumisvuosi:	2023 **Sivumäärä:** 123

TIIVISTELMÄ:

Pelillistäminen eli pelielementtien tai pelimäisten kokemusten lisääminen voi tehdä manuaalisista työtehtävistä mielenkiintoisempia. Pelillistäminen on kasvava tutkimusalue, jota hyödynnetään erityisesti koulutuksessa ja liiketoimintakäytössä. Tässä pro gradu -tutkielma käsittelee pelillistämisen soveltamista MES-tuotannonohjausjärjestelmiin tutkimuskysymyksellä "Miten pelillistetty MES-järjestelmä pitäisi suunnitella?" Tutkimuksen toimeksiantajana on valmistusteollisuuden alalla toimiva yritys yhteistyössä alan kansainvälisen yrityksen kanssa. Tutkimus on osa heidän Teollisuus 5.0 -hankettaan.

Tutkimus koostuu kirjallisuuskatsauksesta, jossa analysoidaan pelillistämistä ja sen sovelluksia vastaavissa tuotantoympäristöissä sekä suunnittelutieteellisen metodin mukaisesta tutkimuksesta. Työssä esitellään pelillistämisen käytäntöjä, menetelmiä, suosituksia sekä kontekstikohtaista tietoa. Suunnittelu- ja kehittämisprosessin perustana on kirjallisuuskatsauksen lisäksi tutkimusaineisto, joka kerättiin haastatteluilla ja havainnoinnin avulla. Tutkimusaineistosta tunnistettiin tietoa kontekstista ja käyttäjistä.

Tutkimuksen päätuloksena on metodiartefakti, joka koostuu suosituksista, joita yritykset voivat käyttää ohjaamaan pelillistetyn MES-järjestelmän käyttöönottoa tulevaisuudessa. Suositukset muodostavat kuusi suunnitteluperiaatetta muun muassa palautteenantoon työhön ja osaamisen kehittämiseen liittyen. Yksitoista käyttöliittymäluonnosta havainnollistavat suunnitteluperiaatteita ja kuvittavat, mitkä pelillistämisen elementit soveltuvat käytettäväksi pelillistetyssä MES-järjestelmässä.

Tutkimuksessa huomioidaan vain työntekijän näkökulma eikä liiketoiminnallisia tarpeita, jotka ovat välttämättömiä pelillistetyn MES-järjestelmän toteuttamiseksi. Siksi jatkotutkimuksessa tulisi keskittyä liiketoiminnan tarpeiden ja tunnistettujen käyttäjien tarpeiden yhteensovittamiseen, artefaktin tarkempaan arviointiin ja artefaktiin perustuvan pelillistetyn MES-järjestelmän toteuttamiseen. Lisäksi tulevaisuudessa voitaisiin tutkia, miten organisaatiossa voitaisiin hyötyä laajemmin pelillistetystä MES-järjestelmästä. Toinen tulevaisuuden tutkimusalue voisi olla pelillistetyn MES-järjestelmän integrointi muihin järjestelmiin, kuten ERP-, CRM-, HR- tai laadunvarmistusjärjestelmiin, palautteen parantamiseksi.

AVAINSANAT: pelillistäminen, MES-järjestelmät, ihmisen ja tietokoneen vuorovaikutus, suunnittelutiede

Contents

Figures

Tables

1 Introduction

Manufacturing and production tasks can suffer from lack of feedback, and repetitiveness, which can lead to errors (Yeow et al., 2014, pp. 3468–3469). The information systems that employees interact with in manufacturing can be characterized as task and production centric. This leads to employees feeding data to the systems in a one-way interaction. But what information could the systems give back to the employees? Gamification could be one way of giving back to the user. By definition, adding game-like elements to non-game contexts (Deterding et al., 2011, p. 10), or enhancing a service to allow for gameful experiences (Huotari & Hamari, 2012, p. 19). Gamification has been proposed as one way of increasing enjoyment and engagement from the user's perspective (Liu et al., 2016, p. 1029). The phenomenon of gamification is a growing area of research, with plenty of research especially in fields such as education and general business processes (Trinidad et al., 2021, pp. 46515–46516).

This thesis presents research on how gamification can be applied to a manufacturing execution system (MES), which is a corporation-wide information system (IS) for managing manufacturing. The work is undertaken as a commission from a company in the industrial manufacturing sector, referred to as the case company. Therefore, the background for the work is set by the case company. For example, gathered data and identified problems are based on what can be found out from the case company. It is being done in cooperation with an international manufacturing company as part of their Industry 5.0 initiative. MES is chosen as the IS to focus on, because it is the main IS used daily by the employees working in assembly. In short, the real-world operating region for this thesis are the two companies, their knowledge, and employees.

Gamification for Manufacturing (GfM) is "a research field in its infancy" (Keepers et al., 2022, p. 314), as it has not been an industry objective thus far (Korn, 2023, p. 252). The field has grown the fastest between 2019 and 2021 but still needs more research for the industry to adopt gamification (Keepers et al., 2022, p. 314). The research of GfM requires deeper understanding of users and system contexts. For example, Keepers, Nesbit, and Wuest (2022, p. 460) claim that prior research does not consider characteristics of the system being gamified or its users. They state that analysis involving system and user characteristics is needed in future research. Wallius et al. (2021, p. 132) add to the need for understanding of users and system contexts by determining that employee perspectives should be considered further in different jobs and organization contexts, to improve understanding of gamification at work. Schuldt and Friedemann (2017, p. 1629) propose prototyping that could enhance empirical research. This thesis is positioned to fill the research gap of consideration for users and the system, as well as supporting prototyping from the point of view of a MES. This thesis implements context and user analysis to further understanding of users and system contexts. Mock-ups are provided to support the prototyping needs of GfM. The research approach is from an employee perspective. Ultimately this thesis provides further research in the field of GfM which Keepers et al. (2022, p. 314) call for.

1.1 Aim and scope of research

The aim of this research is to find out how gamification could be applied to a MES. A MES is a system used to manage production activities, with for example product assembly steps and instructions for assemblers, which is widely adapted in manufacturing (MESA, 1997, p. 3). The case company wants to know what gamification can offer to the employees working and using their MES on the shop floor.

The research question for this thesis is formulated according to the design science research formulation typology proposed by Thuan et al. (2019, pp. 14–17). The problem can be approached by analyzing the areas of concern set for this thesis. Research in this report concerns knowing and designing. This thesis intends, in the way of knowing, to understand what current knowledge there is of gamification in MES or other similar systems. Then based on state-of-the-art knowledge, define guidelines for gamification for MESs. This research intends to produce an artifact. The artifact is a method, defined as feasible but conceptual guidelines (Peffers et al., 2012, p. 4), for gamifying a MES in the context of manufacturing. Thus, the following research question is proposed: *How should a gamified MES be designed?*

This thesis approaches the subject area by following the design research methodology process (Peffers et al., 2007, pp. 52–56) further explained in chapter four. Setting the knowledge base is done by researching the basic principles behind gamification, then prior studies concerned with gamification of industrial production and manufacturing systems. With state-of-the-art principles reviewed, the integral findings are summarized and put into the context of a MES system. The design and development of an artifact method for gamification of MES is preceded by first analyzing the users and their environment. The process continues with problem identification, then setting the objectives. The last two sequences of the design process are the design and development of the artifact and its demonstration. The artifact is demonstrated with mock-ups, which are then evaluated by the case company.

The research conducted defines guidelines on how a gamified MES should be designed, to for instance provide feedback on competence development and allow for privacy and optionality. Important outcomes of this research are the actionable guidelines summed up as design principles, and their demonstration as mock-ups. This thesis contributes to the application environment of manufacturing systems such as MES by providing actionable principles and visual mock-ups for gamifying a MES.

1.2 Structure of the thesis

The thesis is structured as follows. Chapters two and three provide the theoretical background. Chapter two examines the nature, definitions, characteristics, and practices of gamification, while chapter three explores gamification in the context of MES and manufacturing. Chapter four discusses the research methodology.

Chapter five and six apply the previously described theory into practice. Chapter five describes the application environment, the research implementation, and results. The chapter is structured according to the design science process model described by Peffers et al. (2007, pp. 52–56) in chapter four. Lastly, chapter six discusses the resulting artifact, reviews the research conducted, reflects on prior research, and examines its theoretical as well as practical contributions. Finally, this thesis concludes with discussion on limitations of the research and recommendations for future research.

2 Gamification

To understand what prior knowledge there is about gamification in MES, a thorough narrative literature review must be conducted. This chapter reviews the basic mechanisms and core theories behind gamification. The aim of this chapter is to gain an understanding of gamification in general. This chapter is an integral part of the rigor cycle further explained in the methodology chapter. It states that grounding research in the knowledge base is prerequisite to innovative solutions (Hevner, 2007, p. 90).

2.1 Nature of gamification

Gamification as a field combines business, psychology, and game-design (Morschheuser et al., 2018, p. 19). Gamified experiences, meaning the experiences of using a system where gamification has been implemented, can be used for business functions like customer relations, or outcomes like sales. These experiences can be made for external users, such as customers, or internal users, such as employees (Robson et al., 2015, p. 412). Multiple psychological theories involving human needs and motivation are drawn from when considering effective gamification, such as Maslow's pyramid (Maslow, 1943), self-determination theory (Ryan & Deci, 2000), flow theory (Csikszentmihalyi, 2014), and goal-setting theory (Locke & Latham, 1991). Maslow's pyramid states that human needs are set in a hierarchy from basic physiological and safety needs to higher needs like self-realization (Maslow, 1943, p. 18). Self-determination theory (SDT) states that humans are self-motivated and fare better mentally when the needs of competence, autonomy and relatedness are met (Gagné & Deci, 2005; Ryan & Deci, 2000). Frameworks for gamification have widely adapted SDT (Ulmer et al., 2020, p. 671). Flow theory describes the experience of acting in control, whereby a person moves from task to another frictionlessly (Csikszentmihalyi, 2014, p. 136–137). Gamification can be seen as a way to satisfy the forementioned needs, as for example games usually allow for flow states (Csikszentmihalyi, 2014, p. 137).

Gamification is effective because affordances, features that allow for game-like experiences (Huotari & Hamari, 2012, p. 19), later discussed in depth, often lead to positive psychological or behavioral outcomes, like increased usage or engagement (Hamari et al., 2014, p. 3028). Users in experimental studies report mostly positive experiences of gamification (Koivisto & Hamari, 2019, p. 201). However, concern regarding gamification's effectiveness, longevity, as well as ethics, has been expressed.

Gamification's effectiveness is often hindered because it is hard to design. That is for three reasons: the complexity of game-design, the required understanding of motivational psychology, and the need to affect behavior (Koivisto & Hamari, 2019, p. 199). Gamification does work in general, however the application environment and user qualities impact effectiveness (Hamari et al., 2014, p. 3029). For example, research by Hamari (2013, p. 244) posits that environments like utilitarian peer-to-peer trading services steer the user towards rational behavior. Consequently, users might not be interested in game elements such as leaderboards.

Regarding longevity, a newly gamified system can be engaging for some time until it is no longer novel to users (O'Donnell, 2014, p. 356), which indicates the concern for longevity of gamification. Furthermore, research regarding longevity by Koivisto and Hamari (2014, p. 183–184) and Farzan et al. (2008, p. 572) warn of the novelty effect, whereby user interest and effectiveness is high initially. It tends to then decrease over time, thereby decreasing effectiveness. In contrast, Rodrigues et al. (2022, p. 16) posit that the novelty effect of a system can be followed by the familiarization effect, whereby users get used to the system, thereby increasing its effectiveness.

IS design is concerned with ethics, which has been an under-discussed topic for gamification (Keepers, Nesbit, Romero, et al., 2022, p. 314), because comparatively few papers discuss them (Trinidad et al., 2021, p. 46536). Gamification is unethical when, for example, the agenda is hidden to users (Chou, 2019, p. 382) or when it is used in an exploitative, manipulative or harmful way (Kim & Werbach, 2016). One cautionary adaptation of gamification is the Chinese Social Credit System, whereby people are rewarded and punished based on ideology, which violate human rights (Fitzpatrick & Marsh, 2022). However, Marczewski (2017, p. 59) asserts that the ethical implementation of gamification depends on the designer. Effective gamification design should acknowledge the pitfalls and concerns of gamification, which are the difficulty of game-design complicated by psychology, as well as novelty and ethical challenges.

Nonetheless, research by Trinidad et al. (2021, pp. 46505-46517) indicates that gamification has been discussed in the field of education, business, and medicine for nearly five decades. They also indicate that the academic discipline of gamification has been growing exponentially in the 2010's, from seven publications in 2011 to 1082 in 2019. They sum up the discipline's grow as moving from existential questions such as why and what we should gamify, to more practical questions such as how and when we should gamify. Studies have discussed maturing of the discipline and associated growing pains (Vermeulen et al., 2016, pp. 1328–1332), and consequently its maturity has been indicated by Nacke and Deterding (2017, pp. 452–453). Nonetheless Rapp et al. (2019, p. 1) declared gamification to be a "well-established technique in Human-Computer Interaction".

2.2 Definitions of gamification

The most often used and accepted definition of gamification is from Deterding et al. (2011, p. 10) according to analysis by Keepers et al. (2022, p. 313). Deterding et al. (2011, p. 10) define gamification as "the application of game design elements in non-game contexts". This definition according to Huotari and Hamari (2012, p. 19) implies that only "non-games can be gamified". Using a marketing perspective, they highlight the difficulty of identifying a non-game context. Therefore, they offer a differing definition of gamification as "a process of enhancing a service with affordances for gameful experiences in order to support user's overall value creation".

The main difference between the two definitions is that Deterding et al. (2011, p. 10) imply gamification to be based on the application of methods, meanwhile Huotari and Hamari (2012, pp. 19–20) have a broader view. They assess gamification as the process of attempting to increase the chance of gameful experiences by inculcating affordances into a service. Summed up, gamification as such is an umbrella term for attempting to improve for instance user experience and engagement by adopting game elements into non-game-systems (Deterding et al., 2011, p. 10) or by increasing the chance of gameful experiences (Huotari & Hamari, 2012, p. 19). The working definition for this thesis is a combination of these two definitions. Meaning that, this work does search for what game-like elements can be added to the non-game context of MES, while also noting that gamification is a process, whereby there is a search for how the service can be enhanced to allow for gameful experiences, to support creating value for the user. In this context, a MES is being enhanced with gameful affordances to support the providing of feedback, thereby creating value for the user.

2.3 Characteristics of gamification

Even though the definitions for gamification differ as mentioned before, gamification, conceptualized in Figure 1, begins with affordances, e.g., game-like elements that users interact with, which lead to psychological and behavioral outcomes, like increased enjoyment or competence need satisfaction. Hamari et al. (2014, p. 3026) conceptualized gamification as having the three parts of motivational affordances, that result in psychological outcomes and further behavioral outcomes. The overall conceptualization by Koivisto and Hamari (2019, p. 193) has the three parts surrounded by context, which is an important consideration when applying gamification, because the application of affordances as well as their outcomes are contextual (Helmefalk, 2019, p. 6).

Gibson (1977, p. 67) originally defined that "*the affordance of anything is a specific combination of properties of its substance and its surfaces taken with reference to an animal*." Affordances are the features in an environment that make an interaction happen, for example the doorway is a feature of an interior room, that allows for the interaction of walking through it, as long as the person notices the door (Greeno, 1994, p. 340). Zhang (2008) stipulated that all information and communication technology (ICT) should have motivational affordances. Affordances motivate when they involve motivational needs, such as autonomy and competence, resulting in users wanting to use the ICT (Zhang, 2008, pp. 145–147). Extrapolated from there, gamification affordances are features of a gamified system that allow for gameful experiences (Huotari & Hamari, 2012, p. 19). Affordances should be optional in nature, not something the user must interact with (Huotari & Hamari, 2017, p. 26).

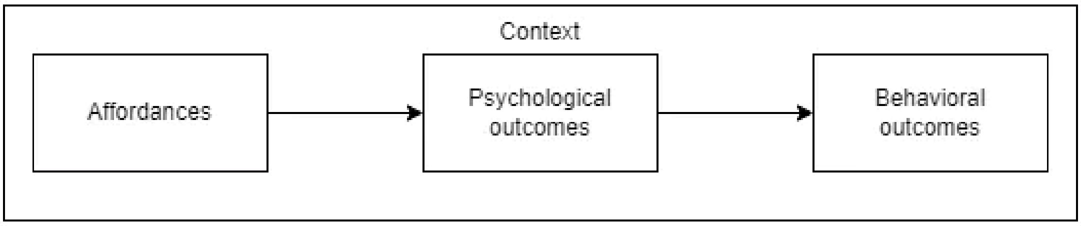

Figure 1. Overall conceptualization of gamification (Koivisto & Hamari, 2019, p. 193).

Gathering a complete collection of affordances in gamification is not possible as many of them are context-specific and hard to typify, but studies summarize some of the most used and popular ones. Koivisto and Hamari (2019, p. 198) studied empirical research papers on gamification and categorized affordances used by type into "achievement/progression", "social", "immersion", "non-digital" and "miscellaneous". The most often implemented affordance type is achievement/progression. Their analysis of affordance implementations points out that points, badges and leaderboards (PBL) are dominant in gamification (Koivisto & Hamari, 2019, p. 198). Helmefalk (2019, p. 9) elaborates on the common mechanics involved with PBL as the common denominator. He specifies that badge-type affordances can be in the form of "achievements" or other unlockable items such as "tokens". Points can be in the form of an "activity counter" or "life". Finally, leaderboards can take the form of "performance graphs" or "ranking". Other often implemented affordances are feedback loops, levels, and progress bars

(Keepers, Nesbit, Romero, et al., 2022, p. 309). The PBL triad is considered the bedrock of gamification. Therefore, most implementations involve PBL, thus empirical evidence indicating its effects is common.

Elements discussed in this chapter can be thought of as a toolbox, which a designer can pull from, and adapt them as a base for their own innovative affordances. The following affordances are also part of the toolbox, even though they might be less popular in literature. The combinations of different mechanics may have complicated effects, as one mechanic could be more or less effective when implemented with another (Helmefalk, 2019, p, 10). Challenges, performance statistics and feedback, and progress bars are examples of less studied affordances. Less implemented affordance types according to Koivisto and Hamari (2019, p. 198) are social, immersion, non-digital elements, and miscellaneous. Social affordances are for example networking features and cooperation. Immersion affordances are for example characters, narrative, and in-game rewards. Non-digital elements are for example financial rewards or motion tracking. Other miscellaneous affordances are, for example, non-descript commercial gamification and virtual assistants. In general, none of the controlled experimental studies are entirely negative, the results are mostly positive mixed with some negative results (Koivisto & Hamari, 2019, p. 202). Pursuing gamification should be worthwhile, even though success might not be guaranteed (Huotari & Hamari, 2017, p. 26). The affordances listed by Koivisto and Hamari (2019) constitutes a holistic view of realistic and exemplified elements that can be considered when gamifying a service.

Coonradt and Nelson (2007) concluded reasons why people would rather pay for difficult free time activities than work for a salary. In other words, hobbies such as gaming often have affordances for discrete goal setting which lets people own their achievements, which are measurable and specific, built-in scorekeeping, active feedback, choice of action, and active self-development. Thus, Coonradt and Nelson (2007) infer these to be the five principles of The Game of Work. Gamified system implementations should strive for the above-mentioned objectives. To reach for the values that make games engaging, should in turn make non-games more engaging. Discrete goal setting could be reached for by motivational affordances such as points and achievements for measuring performance, which would also, with thought-out implementation, include scorekeeping (Suh, 2017, p. 8). Active feedback is a complex game element (Keepers, Nesbit, & Wuest, 2022, p. 458), that can improve performance in group settings (Jung et al., 2010, p. 735). Choice of action is valued in not only hobbies but in workplaces, where employees enjoy freedom of planning and executing their tasks (Wallius et al., 2021, p. 130). Choice of action can be related to the need for autonomy, which according to SDT feeds intrinsic motivation (Gagné & Deci, 2005, p. 336). Self-development such as skill development satisfies needs of competence (Wolf et al., 2018, 2020), which is one of the basic psychological needs outlined in SDT (Gagné & Deci, 2005, pp. 336–338).

The affordances implemented into a gamified solution are expected to have psychological outcomes that lead to behavioral outcomes as conceptualized in Figure 1. Certain affordances lead to certain psychological outcomes, for example achievement affordances like badges and leaderboards can lead to satisfy the “competence need”, while social affordances like characters and narrative can lead to increased “social relatedness” (Sailer et al., 2017, pp. 377–378). Context surrounds outcomes in Figure 1, therefore they are affected by context and domain (Helmefalk, 2019, p. 6). For example, achievement affordances in the education domain have had outcomes of increased engagement and used time of the system (Hakulinen et al., 2015, p. 27). Another example of behavioral outcome is the increased efficiency with points, levels, and leaderboards when implemented into an image annotation task (Mekler et al., 2013, p. 70). Meanwhile, gamification in business contexts tend to focus on profitable outcomes such as increased commitment and willingness to pay (Wolf et al., 2020, p. 356). Helmefalk (2019, p. 17) assert that context determines suitable methods and desirable outcomes.

2.4 Practices for gamification design

Current literature provides guidelines and recommendations for the general designing of gamification. This chapter analyzes current knowledge on The Octalysis Framework by Chou (2019), usability recommendations by Magylaitė et al. (2022), and a design method for gamification by Morschheuser et al. (2018).

Gamification, as a multifaceted practice, requires frameworks for design. Chou (2019, p. 8) presents one such framework called The Octalysis Framework, the level 1 of which is shown in Figure 2. He grounds the framework by contrasting "Human-Focused Design" and "Function-Focused Design" where the former is what gamification should be, systems optimized for motivation instead of the latter, systems optimized for pure efficiency. He puts forward the fact that games are inherently optional while work is not. The eight sides of the octagon in Figure 2 represent the "Core Drives" that motivate users to keep on playing. He describes the system as useful when analyzing current systems, to see how they could be improved.

Chou (2019, p. 58) discusses "Workplace Gamification", characterizing work as often appealing to only two drives: ownership (left-side in Figure 2), to get their salary, and avoidance (bottom-side in Figure 2), to avoid unemployment. Ownership is the drive that motivates users when they feel in control, for example when a user has control over a process in the workplace (Chou, 2019, p. 26). Avoidance is the drive that motivates users to avoid negative events or actions such as losing progress at work (Chou, 2019, p. 28). He describes that generations entering the workforce "are used to being in environments that provide them Epic Meaning, Relatedness, Autonomy and more", thus reinforcing the importance of gamification for the workplace (Chou, 2019, p. 59). These are the drives of Figure 2 shown as meaning on the topside, social influence (relatedness) on the right-side, and empowerment (autonomy) on the top right oblique side in the Octalysis Framework. Moreover, he adds that workplaces should empower creativity. Meaning is the drive that motivates because they contributing to something bigger than themselves.

Relatedness and Social Influence is the drive that motivates humans because we are social animals and care what “other people think, do, or say (Chou, 2019, p. 195).

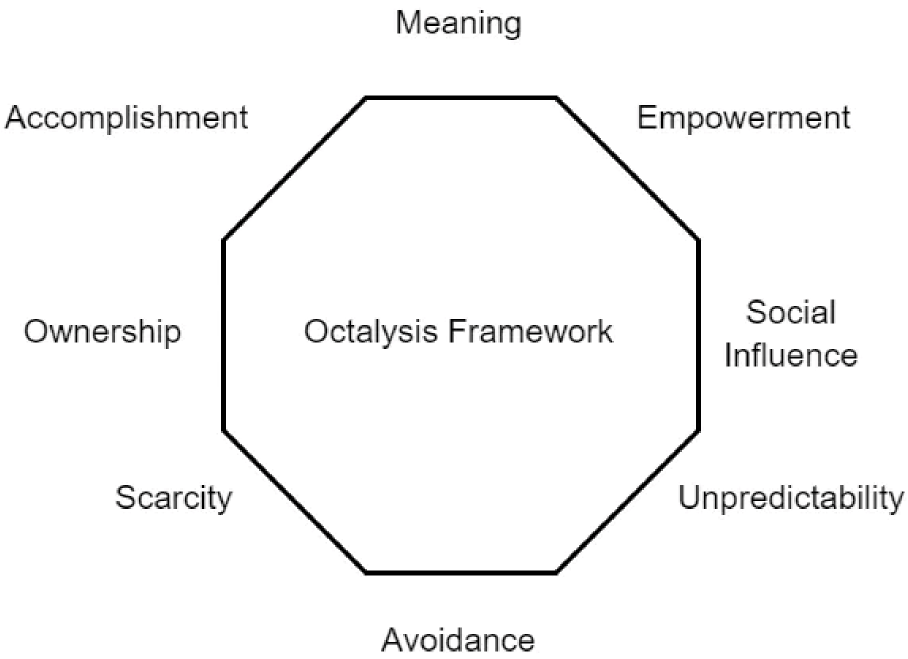

Figure 2. The Octalysis Framework (adapted from Chou, 2019, p. 23).

However, Chou (2019, pp. 207–211) warns of the difficulty of creating workplace competition, as it can demoralize and create unhealthy working environments. This is in line with findings from Riar et al. (2022, p. 15), who posits that individual design can produce unhealthy competition. Research by Alavesa et al. (2019, p. 2) and Wallius et al. (2021, p. 130–131) also noted that their workplace contexts, factory floor and logistics, are not fit for competitive elements. Work by Chou (2019, pp. 58–59) indicates that gamification for the workplace should aim to give meaning, relatedness, autonomy, as well as empowerment of creativity and feedback. It should be noted that Chou (2019) does not describe what affordances to implement, moreover he describes what gamification characteristics should be brought into the workplace.

Usability is important in human-system interaction, as it has been codified into ISO standards. The International Organization for Standardization (2018) defines usability as “the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use”. Their standard implies that usability principles among other human factors need to be focused on when aiming for human-centered design (International Organization for Standardization, 2019). Magylaitė et al. (2022, pp. 7–8) have summarized usability recommendations from gamification literature. The most mentioned guidelines focus on learnability, such as feedback, familiarity, and relevance. Learnability is a sub-characteristic of the usability characteristic defined in ISO 25010 standard’s product quality model (International Organization for Standardization, 2011). Systems should communicate to users using familiar terms. The use of various mediums like visuals and sounds instead of only text, the modality principle (Mayer, 2020), can improve learnability. Gamified actions should stay relevant to system goals, with clear design and structure of visuals to avoid confusing the user (Magylaitė et al., 2022, p. 7).

Other general recommendations have to do with user control, system communication, as well as visual design and clarity. Users should be able to accomplish tasks as they see fit or even disable gamification. Gamification elements should be communicated clearly and consistently including clear error messages and recognizable functions. Further recommendations adapted from Magylaitė et al. (2022, p. 7–8) are included in Appendix 1. According to their research, most recommendations were general and not actionable as is. Research by Spahrbier et al. (2022, p. 13) supports the importance of usability in gamification. By following ISO-9241 standards of usability and human-centered design (International Organization for Standardization, 2019), among other UX considerations, they were able to increase “work attractiveness”. Thus, usability should be considered amongst other UI/UX considerations when designing gamification.

Focusing on actual implementation of gamification rather than general notions on usability or design, Morschheuser et al. (2018) synthesized knowledge on design principles that can be used when designing and engineering gamification. They presented 13 design principles, based on literature review and expert interviews. They are adapted with explanations in Table 1, leaving out design principles 10 and 11 that are out of research scope. The overarching theme of their design principles is that design should be user centric. Meaning that designers should understand the user and what motivates them, focus on their needs, and involve them in ideation, for example. It also means that designers should get user feedback as early and as often as possible. In the bigger picture, designing gamification is not only about understanding game-design, but also understanding motivational psychology. Defining objectives, metrics and monitoring is integral to achieve success, as is the nature of development projects (Morschheuser et al., 2018, pp. 13–14).

Table 1. Design principles for gamification (adapted from Morschheuser et al., 2018, p. 10).

Design principle	Explanation
DP 1. Understand user needs, motivation and behavior, as well as the context	Profound analysis of target users and operational context of the system should be applied. Focusing on users' needs trumps business needs.
DP 2. Identify project objectives and define them clearly	Clear project goals are imperative for evaluation of success and for guiding the project.
DP 3. Test gamification design ideas as early as possible	Testing designs often leads to most appropriate design for users, and further investment into wrong actions can be avoided.
DP 4. Follow an iterative design process	Gamification engineering is an agile development process, where design fails should be quickly addressed, and the user experience is continuously optimized.

Design principle	Explanation
DP 5. Profound knowledge in game-design and human psychology	Gamification should be designed holistically, taking into consideration game design and human motivation. Knowledge, creativity, and experience is required for high-quality design.
DP 6. Assess if gamification is the right choice to achieve the objectives	The need for gamification should be assessed, as it might not always be the solution for the problem addressed.
DP 7. Stakeholders and organizations must understand and support gamification	The lack of key stakeholder involvement may lead to failure. They should thus be involved from the beginning, ensuring that everyone shares a common understanding of gamification and the project goals.
DP 8. Focus on user needs during the ideation phase	User requirements are to be prioritized over business requirements. The motivating power of a gamification solution is dependent on fulfillment of user requirements.
DP 9. Evaluate and monitor the success, psychological and behavioral effects of a gamification approach with defined metrics	The metrics for evaluating and monitoring effects of gamification should be defined at the beginning of the engineering process. They can be utilized to for example evaluate success or whether mechanics need to be adjusted.
DP 12. Consider legal and ethical constraints in the design phase	The lack of consideration for legal and ethical constraint may lead to failure. It is imperative to avoid infringing on rights such as intellectual property.
DP 13. Involve users in the ideation and design phase	Involving users can be in the form of for example routine user testing to ensure the design aligns with user requirements.

Based on these principles, Morschheuser et al. (2018, p. 13–23) derive a method for engineering gamified software, calling it a “method of methods, since it synthesizes prior frameworks”. They map design principles into seven phases of their method. Their last three phases of implementation of design, evaluation, and monitoring are left out of Table 2 as they are out of scope for this research. This is because the objective is not to implement the design. Furthermore, the evaluation and monitoring of design implementations requires the defining of metrics as well as a longer timeframe, which are unattainable in this thesis.

Table 2. Method phases mapped to Design Principles (adapted from Morschheuser et al., 2018, p. 13).

Method phase	**Design principle(s) no. reflected in the method phase**
1. Project preparation	2, 6, 7, 9.
2. Context and user analysis	1.
3. Ideation	8, 13.
4. Design	3, 4, 5, 12, 13.

This thesis, as defined in the introduction, has its scope limited to design, which is the fourth method phase in Table 2. Therefore, the first to fourth method phases in Table 2 will be further explained in the following paragraphs.

The development of gamified software should begin with method phase one, project preparation, with Morschheuser et al. (2018, p. 13) recommending a creation of a project plan. It should be used to identify, list, rank, and justify objectives, accordingly with design principle 2. The defined objectives can then be used to derive measurements accordingly with design principle 9. Before going ahead with the project, accordingly with design principle 6, it should be assessed whether gamification is suited to achieve the defined objectives. Communicating objectives to stakeholders accordingly with design principle 7 should also be considered.

Moving on to phase two of the method by Morschheuser et al. (2018, pp. 14–16), context and user analysis should be conducted in accordance with design principle 1. User analysis can be conducted via, for example, interviews or observations of users. Thus, user groups can be described into, for example, fictional personas that represent types of typical users and their characteristics such as age, activities, needs, and preferences. Context analysis can be conducted via for example creation of process models, scenario analysis or user journeys to define the context characteristics such as processes, platform, and architecture.

Phase three of the gamification design methodology by Morschheuser et al. (2018, pp. 14–16) is ideation. It is especially characterized by focus on the users. They align this phase with design principle 8, whereby the selected game elements should be aligned with user requirements. In addition, ideation can draw from features known from games and seeing how they can be used to motivate users toward goal-oriented behavior. Morschheuser et al. (2018, pp. 14–16) encourage creativity when brainstorming ideas, therefore innovative features do not have to be those readily found in games. They suggest that the ideation phase could produce a consolidated list of ideas.

The fourth phase in the method by Morschheuser et al. (2018, p. 18–19), and the last phase in scope of this thesis is the design phase. They define that the results from the ideation phase should be, in accordance with design principle 3, developed in to prototypes such as wireframes. They add that the design should follow an iterative process per design principle 4. Morschheuser et al. (2018, p. 18) suggest that this phase can result in, for example, a development concept after prototype evaluation. However, in the case of this thesis, the creation of the prototype is the phase’s final activity.

Other methods for implementing gamification in business contexts are presented by Klevers et al. (2016) and Kumar (2013). They both present a step-by-step model, with different number of steps or phases. The “process called Player Centered Design” by

Kumar (2013, p. 9) is five-phased and the "GameLog Model" by Klevers et al. (2016, p. 3) is three-phased. Kumar (2013, p. 35–47) recommends first analyzing the user and creating a "player persona" of the usual user. Her player persona is especially useful when thinking about user analysis, as she points out concrete information that is useful when designing gamification. Then she calls for setting the mission, motivation, mechanics and monitoring for gamification in enterprises. Klevers et al. (2016, p. 3–4) suggest starting by analyzing and exploring, which includes analyzing basics of the business process, to find out where gamification does not interfere with core processes. Their guidelines on context analysis are especially useful, as they point out that examination of the work process should be conducted. After designing they propose the design and development phase, starting with selecting game mechanics based on goals that turn into game elements. Finally, they suggest evaluating and reflecting on the implementations, and redesigning as needed. Like with the method by Morschheuser et al. (2018), this research has iteration and monitoring out of its scope. These methods seem similar, while the method by Klevers et al. (2016) is the shortest, and the method by Morschheuser et al. (2018) is the most complicated and thorough, with Kumar (2013) somewhere in between.

This chapter reviewed the definitions, conceptualizations, and characteristics along with practices of gamification. The basis of gamification was presented as involving multi-disciplinary knowhow of business, game design and psychology among others. Maslow's theory (Maslow, 1943), SDT (Gagné & Deci, 2005; Ryan & Deci, 2000) along with flow theory (Csikszentmihalyi, 2014) are among the psychological theories gamification draws from. Problems of ethics are up to the designed and unethical use of gamification (Chou, 2019; Kim & Werbach, 2016). The general history of the field was presented as recently grown and established into the field of HCI (Rapp et al., 2019). Two definitions were presented, which varied in their point of view. Deterding et al. (2011) define gamification as merely applying game design to non-games, while Huotari and Hamari (2012) differ, identifying gamification as higher-order process of enhancement. Gamifications characteristics were identified as consisting of affordances, its resulting psychological and further behavioral outcomes, which is surrounded by context of application (Koivisto & Hamari, 2019). For this thesis, affordances were further elaborated on because they are where gamification's effects begin. The practices reviewed should provide insight into how humans are motivated by gamification and how to design it. The Octalysis Framework (Chou, 2019) reviewed concerning workplace gamification prepares ground for review of knowledge specific to. The meta-artifact of how to design gamification (Morschheuser et al., 2018) and similar methods (Klevers et al., 2016; Kumar, 2013) inform the design and development of the artifact as a result of this thesis.

3 Gamification in the context of a MES

After analyzing gamification basics, analysis on gamified manufacturing is required for the knowledge base of this thesis. This chapter analyses what gamification mechanisms and theories are applicable to the specific context of MES and manufacturing. The context of manufacturing has specific characteristics, which can differentiate it from other workplace contexts analyzed in this literature review.

This chapter discusses prior research about gamification for manufacturing, production, and industrial production. The different terms are discussed interchangeably in this review because the terms vary across literature without the meaning changing for this research. Be it industrial production or manufacturing that literature is discussing, it is useful knowledge for this thesis. There may be practical differences between these fields when it comes to core business processes. But this chapter focuses on gamification in the context of a MES, which can be used in many fields of manufacturing or production.

3.1 MES conceptually

A Manufacturing Execution System (MES) is part of the architecture of a Process Control System. It can be implemented in between the Enterprise Resource Planning (ERP) layer and the control layer in the traditional automation pyramid (Mersch et al., 2010, p. 1). It is one of the major information systems used in manufacturing, among for example ERP, Supply Chain Management (SCM), and Sales and Service Management (SSM) systems (MESA, 1997, p. 4). They are used to centralize information about manufacturing processes for managing and improving “process transparency, efficiency improvement, on-time performance, and compliance with production plans” (Chen & Voigt, 2020, p. 1). The international community for manufacturing MESA (1997, p. 3) has defined MES as follows:

> Manufacturing Execution Systems (MES) deliver information that enables the optimization of production activities from order launch to finished goods. Using current and accurate data, MES guides, initiates, responds to, and reports on plant activities as they occur. The resulting rapid response to changing

> conditions, coupled with a focus on reducing non value-added activities, drives effective plant operations and processes. MES improves the return on operational assets as well as on-time delivery, inventory turns, gross margin, and cash flow performance. MES provides mission-critical information about production activities across the enterprise and supply chain via bi-directional communications.

Based on the above-mentioned description of MES, such systems are a prime example of having the purely function-focused design as described by Chou (2019, p. 8). Focus on function is characteristic of the Industry 4.0 paradigm, which focuses more on “smart, efficient, effective, individualized and customized production at reasonable cost” (Vaidya et al., 2018, p. 237). The next paradigm in manufacturing, called Industry 5.0, is described as the paradigm of human-centric, sustainable, and resilient manufacturing (European Commission et al., 2021, p. 25-28). Thus it can be described as focusing more on human-focused design, which Chou (2019, p. 9) prefers in “real-world or productive” systems. Industry 5.0 changes to systems might be most apparent to the user from changes to the user interface, or completely new user interfaces. A MES can have a unified user interface (Shojaeinasab et al., 2022, p. 516), where gamification is most noticeable by the user.

3.2 Background of gamification for manufacturing

The field of gamification in the context of production systems has grown in recent years (Keepers, Nesbit, Romero, et al., 2022, p. 313). Production process control and execution systems have been the most recurring subject of gamification research’s current body of literature (Warmelink et al., 2020, p. 338). Still, gamification for manufacturing (GfM) is an underrepresented area within the field of gamification research. For example, out of over 17 000 papers published in 2019 regarding gamification, only 16 directly regarded gamification in manufacturing (Keepers et al., 2020, pp. 112–113). Only recently has the need for gamification in manufacturing been noticed, with the amount of research papers positively trending in the years 2019 to 2021 (Keepers, Nesbit, Romero, et al., 2022, p. 313).

Korn (2023, p. 252) describes the need for gamification in industrial production stemming from the changing expectations of newer generations entering working life. He identifies that these generations are more sensitive to react to the design of systems. This need is additionally reinforced by Chou (2019, pp. 58–59) calling for workplace gamification. In his earlier studies Korn (2012, p. 316) describes that gamification for production systems were thought to be needed to motivate special groups such as elderly or impaired persons, when recently games and gamification is normalized in the lives of the general public (Korn, 2023, p. 252).

Understanding the context where gamification is being applied is important. For example, the features of the factory floor setting should be noted. Alavesa et al. (2019, p. 2) define four features that are specific to the factory floor setting. Firstly, they posit that factory floors tend to have varied demographics such as a wide range of ages and not all are digital natives. Secondly, employees are motivated by work. Thirdly, high collaboration and the motivating aspect of collaborative flow describe the work atmosphere instead of competition. Alavesa et al. (2019, p. 2) conclude that the previously mentioned features should be adapted to existing guidelines as to suit them for the factory floor.

Research by Wallius et al. (2021) seems to agree with the features laid out by Alavesa et al. (2019). The work community studied by Wallius et al. (2021, p. 133) posits that good qualities of work, such as freedom to plan tasks and solve problems, are main motivators. This aligns with the second feature defined by Alavesa et al. (2019, p. 2). They also posited that their context, maritime logistics, was not well suited to competitive affordances. This aligns with the third feature defined by Alavesa et al. (2019, p. 2). Wallius et al. (2021, p. 133) found out that there might be a difference between generations on how gamification is perceived, as newer generations tend to be familiar with games. Older generations that are not familiar with games tend to still work in manufacturing, so this feature of the demographic should be taken into consideration, accordingly with the first feature described by Alavesa et al. (2019, p. 2).

3.3 Guidelines for designing gamification in manufacturing context

Korn (2023, p. 267) provides guidelines for designing gamification for production. He bases it on the "bottom-up" approach described by Lessel et al., (2016, p. 2035) whom posit that users want to "decide when, where and how to gamify aspects of their life". This is in line with the user-focused design principles described by Morschheuser et al. (2018), whereby users should be involved from the beginning and throughout the process from preparation to design and beyond. Korn (2023, p. 267) supplements the principles set by Morschheuser et al. (2018, p. 10) with eight guidelines for gamification in production:

1. Keep it simple. For example, the use of simple static design can be used to avoid distraction from the production work task.
2. Keep it close. For example, the use of monitors or projection integrated in the workspace can be used to avoid distraction and provide information directly on top of the work product.
3. Give user control. For example, users should be allowed to switch off gamification elements to avoid distraction in challenging situations.
4. Mind the quality paradigm. Gamification design should incorporate feedback on not only speed but quality.
5. Match the challenge to user level. Avoid wrong adaptations of challenge level by tracking user status by for example integrating basic emotion tracking.
6. Provide interesting challenge variety to avoid boredom.
7. Provide anonymity. Personal data like the history of user performance should be purposefully used for gamification and not stored or communicated to other systems.
8. Design gamification adequately. Users should be involved in a bottom-up design process to evaluate what characteristics of gamification work best in their specific production settings.

Many of Korn's (2023, p. 267) guidelines can be reflected to align with aforementioned design principles (Morschheuser et al., 2018, p. 10) and usability guidelines (Magylaitė et al., 2022, pp. 7–8). For example user control is mentioned by Korn (2023, p. 267) in guideline 3 and by Magylaitė et al. (2022, p. 7) as a usability recommendation. The importance of gamification design quality is mentioned by Korn (2023, p. 267) in guideline 8, and by Morschheuser et al. (2018, p. 10) in design principle 5 (see Table 1), not forgetting its basis on bottom-up design (Lessel et al., 2016).

From general guidelines to affordance-specific considerations, Keepers, Nesbit, and Wuest (2022, p. 458) have formulated a classification framework for game elements for manufacturing. Considering their framework and how they apply to a project at hand can provide guidance on what game elements should be considered for the targeted system They determined three dimensions in which game elements can differ:

1. Simple vs. complex, which is a resource-dependent consideration, for example does the project have enough time or expertise for complex elements. Simple elements are universally used elements such as points and badges. Feedback or storylines require more resources.
2. Individual vs. group, which is context-dependent, for example employees might prefer working as a group, so the elements should reflect that. Progress indicators are individual elements as they require only one person, whereas for example competitive elements require a group.
3. Intrinsic vs. extrinsic motivation, which is design-preference, for example which elements are thought to be appropriate and desired. Elements that offer no rewards in the workplace are intrinsically motivating, whereas elements that are extrinsically motivating offer social status or workplace incentives such as bonuses.

The categories of simple vs. complex, individual vs. group and intrinsic vs. extrinsic motivation form eight groups of game elements classified in Table 3. It is worth noting how complex elements like narrative or problem solving might require more expertise to implement compared to simple elements like notifications and progress bars. Keepers, Nesbit, and Wuest (2022, p. 457) note that game elements in extrinsic columns (group no. 2 4, 6 and 8) have more elements because they are easier to measure, and furthermore the group columns (groups 4 and 8) have more elements because they include competition.

Table 3. Game elements classified into suitable columns (adapted from Keepers, Nesbit, and Wuest, 2022, p. 458).

Group and Descriptor	**Elements**
Group 1. Simple, individual, intrinsic	Notifications, personal goals, increasing complexity, constraints.
Group 2. Simple, individual, extrinsic	Progress bars, goals, strategy, time constraints, increasing complexity, loss aversion, displaying performance, badges, rewards, achievements, awards.
Group 3. Simple, group, intrinsic	Collaboration, interaction, teammates.
Group 4. Simple, group, extrinsic	Displaying performance, collaboration, interaction, leaderboards, competition, teammates, ranking, awards, point system, scoring system, contests.
Group 5. Complex, individual, intrinsic	Constraints, story elements, avatars, emotion, narrative, problem solving, puzzle games, scenarios.
Group 6. Complex, individual, extrinsic	Badges, rewards achievements, awards, levels, feedback, quests, virtual goods, boss fights, challenges, mission, rules, content unlocking, performance groups.
Group 7. Complex, group, intrinsic	Discussion boards.
Group 8. Complex, group, extrinsic	Awards, point system, scoring system, contests, performance graphs, discussion boards, betting, social recognition.

Additionally, same elements are in more than one group depending on application context and task interpretation (Keepers, Nesbit, & Wuest, 2022, p. 457). It stands that affordances are highly contextual, as systems are often built as customized for specific purposes (Helbig et al., 2016, p. 393). It should be noted that the affordances discussed by Koivisto and Hamari (2019, p. 199) constitute a wider lens on what game elements have been used in gamification, compared to the more specific lens on manufacturing discussed by Keepers, Nesbit, and Wuest (2022, p. 458). The most common affordances in production execution and control are goals and objectives, multimedia feedback, and metaphorical representation (Warmelink et al., 2020, p. 334). The affordances listed by Koivisto and Hamari (2019, p. 199) have similarities to the elements listed in Table 3. Combining knowledge about the elements can be used for well thought out justification for the use of a certain element in a gamification implementation.

In the context of this research, manufacturing is a cooperative activity, and thus it is worthy to consider gamification of cooperation. Riar et al. (2022, pp. 3–4) specify cooperative elements inherent in online games, such as social factors and team performance could drive collective engagement in work involving non-game systems. As a result, they have identified 21 different gamification features, such as the most popular feature: points or score, as well as challenges or goals, achievements, progress or levels, and leaderboard or ranking among others (Riar et al., 2022, pp. 5–8). They propose three design approaches dependent on who to reward: individualistic, collective or hybrid. They outline each approach’s nature, strengths, and weaknesses followingly. Individualistic design approaches motivate to cooperate based on benefits for oneself, such as personal points and achievements. Such an approach is well-established and easy to apply. Its’ weakness lies in the possibility of unhealthy competition rather than cooperation. Collective design motivates based on “collective benefits” such as team progress and shared resources. It can bring people together and strengthen social dynamics. As a weakness it can neglect good individualistic features. Hybrid design is a blend of both, with for example individual and team goals. By combining individualistic and collective design, a combined motivational effect can be achieved. Thus, the user is motivated by their own tasks as well as the teams’ best interest. It nonetheless has a risk for conflict-of-interest, whether to focus on own or team goals for example. A designer should choose what design approach fits best depending on their context. (Riar et al., 2022, pp. 15–18).

The framework defined by Ulmer et al. (2020, p. 673) posits that a scoring and skill system should be the core components of a gamification application. They specify that a scoring system benefits both the user, by regular feedback, and the company, by finding productive employees whose workflows can be analyzed and replicated. They specify that the skill system should be composed of expertise records which the user must have at least one of. Each expertise has corresponding aptitudes or activities, which they exemplify in Table 4. The skills one could earn are reminiscent of achievements or badges, which can be designed by using for example the achievement framework defined by (Hamari & Eranti, 2011, p. 16).

Table 4. Skill system structure and example (Ulmer et al., 2020, p. 673).

Specialist track:	**CNC machines:**
Field of activities 1: Corresponding activity 1 Corresponding activity 2	Programming: 3-axis 4-axis
Field of activities 2: Corresponding activity 1 Corresponding activity 2	Maintenance: Spindle Tool changer

Ulmer et al. (2020, p. 673) outline that work environments should be “capable of providing digital work information on time, automatically evaluating the actions of the user, and showing correction information if necessary”. They do not mention that the work environment needs to have a clear understanding and structure of skills. This is prerequisite to divide skills into such discrete fields. Hamari and Eranti (2011, p. 16) define designing for achievements, like skills, to require signifiers (name, visuals, description), completion logic (trigger, condition, requirements) and reward (in and out of the game).

3.4 Summary and research gap

Literature reviewed identified future research avenues for GfM. Keepers, Nesbit, Romero, et al. (2022, pp. 314–315) call for empirical research, design element impact assessment and guidelines on what elements to use in different use cases and their potential benefits. Keepers, Nesbit, and Wuest (2022, p. 460) call for development of a framework based on characteristics of production system or the operators involved. Wallius et al. (2021, p. 132) asses that research should delve into employee perspectives of gamification in different jobs and organizations to their own research, because they can add to knowledge regarding gamification at work. Schuldt and Friedemann (2017, p. 1629) propose the development of gamification prototype applications that would facilitate further empirical research, wherefore improved guidelines could be made.

This chapter is part of the rigor cycle (Hevner, 2007, pp. 89–90) on gamification. The chapter was initialized by defining MES and situating it between other organization-wide information systems. Brief history and background for GfM was identified as a growing field that is needed to engage new generations (Keepers et al., 2020; Keepers, Nesbit, Romero, et al., 2022; Warmelink et al., 2020). Not forgetting current context considerations for work environments (Alavesa et al., 2019; Wallius et al., 2021).

The recommendations, guidelines, and frameworks reviewed in this chapter act as the setting of the current knowledge base on gamification in the context of industrial production systems and manufacturing. Guidelines specific to production and manufacturing were presented (Keepers, Nesbit, & Wuest, 2022; Korn, 2023), which support previously introduced general guidelines. The collective nature of manufacturing required consideration for cooperative design approaches (Riar et al., 2022). Specific suggestions for core components were introduced as a scoring and skill system (Ulmer et al., 2020).

These existing research solutions fall short of meeting the objective of informing how specifically a gamified MES should be designed. The guidelines by Korn (2023, p. 267) fall short as they are generic guidelines suggested for gamification in the industry of manufacturing, and not specific enough for MES. The guidelines are however usable solution component for further iteration in this research, as they provide useful guidelines that are applicable to the gamification of a MES. The classification framework by Keepers, Nesbit, and Wuest (2022, p. 458) informs the design of affordances, and thus is a reusable solution component. It still falls short, as the framework defines the nature for affordances, without defining what affordances are suitable for what context. The cooperative design approaches defined by Riar et al. (2022, pp. 15–18) are reusable to inform what particular cooperative design suits the context and users at hand. As they are definitions of design approaches, they fall short as to what suits the users and MES specifically. The framework for the skill and scoring system defined by Ulmer et al. (2020, p. 673) is yet another framework which falls short because of its generality. It posits the core components for GfM as scoring and skill system, therefore the information can be reused to design a scoring and skill system which suits a gamified MES. Thus, these existing solution components inform the design problem of how a gamified MES should be designed.

4 Design Science Research

This thesis uses Design Science Research Methodology (DSRM) as the main methodology of research, with qualitative data collection and analysis. Design science is concerned with problem-solving and innovation. Such research is characterized by scientifically proven knowledge and principles that are intended to solve real problems (Gregor et al., 2020). By designing new solutions to known problems or applying known solutions to new problems, research conducted with DSRM produces innovative design artifacts. This chapter explains design science research's (DSR) cycles, guidelines for conducting, the DSRM process model and the qualitative data collection and analysis methods. Each theory's application to this research is elaborated on.

4.1 Design science research cycles

DSR is characterized by three research cycles, which are relevance, design, and rigor cycles overlaid on the IS research framework shown in Figure 3 (Hevner, 2007; Hevner et al., 2004). The relevance cycle is characterized by setting the requirements and starting DSR. The cycle should iteratively repeat until the quality of the artifact is sufficient and the solution is relevant.

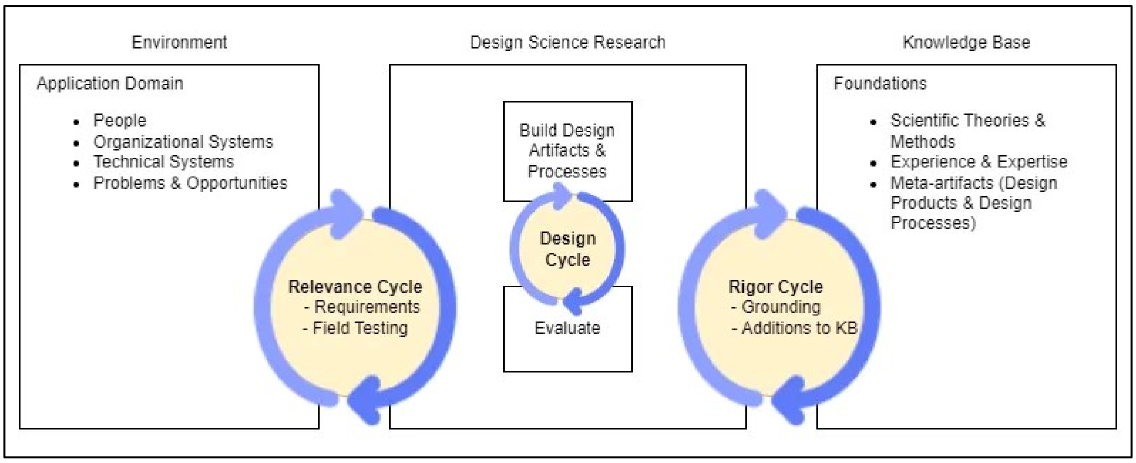

Figure 3. Design Science Research Cycles (Hevner, 2007, p. 88).

The rigor cycle grounds DSR in prior knowledge, to facilitate innovative solutions. Thus, the researcher knows what known solutions are and what are new additions to the knowledge base. The rigorous grounding to prior knowledge must not hamper innovation, as core theories are not always available to apply to innovative ideas. Additions to a knowledge base are for example results that extend theories, new ways to do design, and the experiences of researching and testing an artifact in its application environment.

The design cycle is the core iterative process in a design science research project. The two other cycles feed the design cycle with requirement-setting and grounding, for actual design to take place. The cycle of design should iterate in balance without forgetting either one, between construction and evaluation. Thus, the artifact can fit the requirements, be well grounded in theory, and be the best possible solution in the application environment (Hevner, 2007, p. 91).

Chapters two and three are part of the rigor cycle. In the beginning of chapter five the application domain is analyzed, setting the requirements, thus it is part of the relevance cycle. The knowledge acquired from the relevance and rigor cycle feeds into the design cycle of this thesis, whereby the design artifact is built and demonstrated. The research cycles represent work that can be done repeatedly, and at the same time, meaning that for example during the design cycle, a relevance cycle is in effect at the same time. Therefore, revising requirements for the design cycle. Repeated cycles represent future work and are not in the scope of this thesis.

4.2 Design science research guidelines

The design science research guidelines for information systems research presented by Hevner et al. (2004, pp. 82–90) are aligned with the objectives of this research as follows:

1. “Design as an Artifact”, meaning that a viable artifact must be produced in the end. This research intends to achieve this in the form of actionable guidelines

that could further gamification for manufacturing in the application domain of a MES and the case company's context.

2. "Problem Relevance", meaning that the artifact should present a technological solution to a business-relevant problem. This thesis is business-oriented and aims to present gamification-based solutions to align the case company's MES with employee needs.
3. "Design Evaluation", meaning that the artifact's usefulness should be methodically evaluated. The proposed artifact will be applied to conceptualized illustrations in the form of UI-mock-ups. These illustrative scenarios will then be evaluated by the case company.
4. "Research Contributions" meaning that the research conducted in this thesis contributes to the field, in this case the field of gamification in manufacturing. The artifact intends to contribute by defining possibilities for gamification in MESs brings to the field of Gamification for Manufacturing (GfM).
5. "Research Rigor" meaning that the research methods used to construct and evaluate the design artifact are according to best practices and methods. This thesis is put together with guidance from the leading research papers in the field of Design Science Research, authored for example by Hevner et al. (2004); Peffers et al. (2007, 2012) and Thuan et al. (2019).
6. "Design as a Search Process" meaning that the research should be characterized as a search for the best solution that fits well in the chosen environment. This thesis analyzes the prior knowledge available for gamification for manufacturing systems, searching for prior solutions where the user is the focus. Only then can the design artifact take shape and be applied to the target environment of the case company's MES.
7. "Communication of Research" which means that the research must be understandable by both "technology-oriented", and "management-oriented" groups interested in the findings. As this research is both a thesis and commissioned work for the case company, utmost attention is paid to satisfy

both parties. Interviews conducted with both users and upper-level management and developers will ensure communication of research inside the case company. The success of the guidelines' application is assessed in the discussion of alignment with DSR guidelines (Chapter 6.2).

Gregor and Hevner (2013, pp. 345–347) elaborate on how DSR contribution should be presented. They introduce the DSR Knowledge Contribution Framework, whereby research contributions can be categorized according to their application domain maturity and solution maturity. If a known solution is applied to a mature application domain, it is routine design, which usually does not contribute to research. If the known solution is instead applied to a new application domain, it is exaptation. An improvement contribution is reached when new solutions are developed in a known application domain. Inventions are new solutions to new problems, making them the rarest kind of contribution. This thesis represents an improvement contribution, because it applies the new addition of gamification to a known system of MES in the known domain of manufacturing. The contribution this research makes is discussed further in the discussion on key results and contributions (Chapter 6.1).

4.3 DSRM process model

This thesis follows the DSRM process model defined by Peffers et al. (2007, pp. 52–56), in which they have defined a widely accepted framework for conducting Design Science research. The research process overview for this thesis is defined by applying their nominal process sequence's six activities. As shown in Figure 4, the six activities of the nominal process sequence are problem identification and motivation, objectives of the solution, design and development, demonstration, evaluation, and communication. According to Peffers et al. (2007, p. 49), their process model closely follows the practical rules of conducting Design Science research laid out by Hevner et al. (2004), which this thesis is aligned with above. That is why they add contribution in their process model as the seventh activity. Thus, the DSRM research process overview for this research will repeat some principles that have been aligned with the practical rules. Peffers et al. (2007, pp. 52–56) define resources required for each activity.

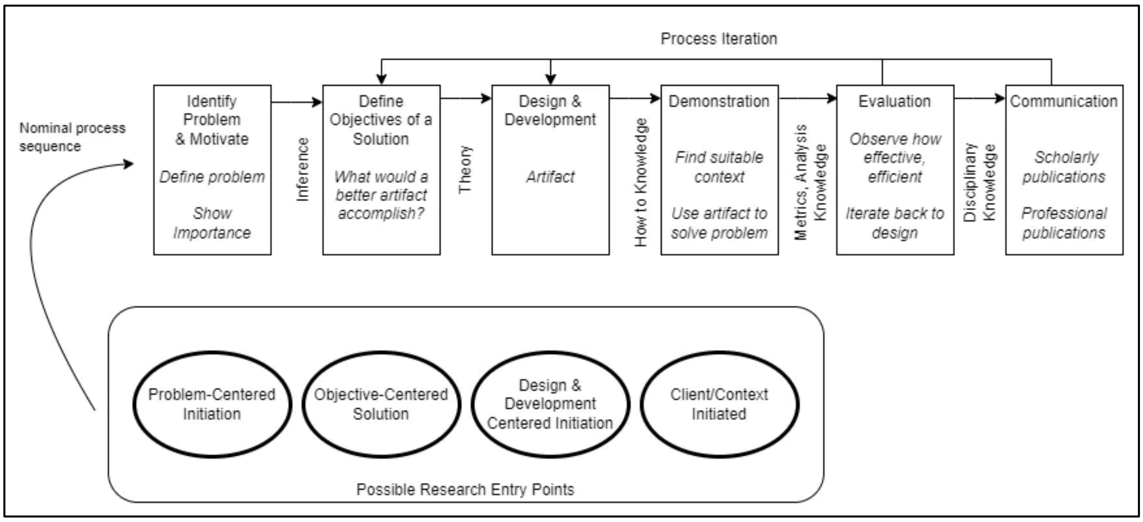

Figure 4. DSRM Process Model (Peffers et al., 2007, p. 54).

Peffers et al. (2007, p. 56) detail how research proceeds using the DSRM process model. The model is presented as a sequence in Figure 4, but they explain that research does not have to start from left to right. Instead, it can begin at any step depending on the research entry point. For example, the process would start at the first activity of the sequence, problem identification and motivation, if the "idea for the research resulted from observation of the problem".

4.3.1 Problem identification and motivation

The first activity in the nominal process sequence by Peffers et al. (2007, pp. 52–55) is the problem identification and motivation. They specify that problem identification is important to do so the artifact can be an effective solution. This means conceptualizing problems so that the solution can meet the intricate needs. Problem motivation means giving reasons as to why the solution is worth pursuing. Knowing the problem, and how important it is to solve, is required for this activity. In this research, the case company's knowledge of the problem and their motivations on the importance of the solution are used.

4.3.2 Objective-centered solution as research entry point

The research process in this thesis has its entry point as an objective-centered solution, because the need for human-centricity is triggered by the industry. Therefore, the research process itself starts at defining the objectives of the solution. Reporting is however done according to the nominal process sequence (Figure 4).

Peffers et al. (2007, p. 55) recommend basing the objectives of a solution on the problem identification, making it the second activity in the sequence. The process in this research starts by defining the objectives of the solution. Therefore, problem identification comes after defining objectives in this thesis. Peffers et al. (2007, p. 55) suggest that the objectives can be quantitative, such as the features needed for an improved solution, or qualitative, such as how the artifact solves unaddressed problems. Knowledge of the current situation's problems, and current solutions, is required to define objectives.

4.3.3 Design and development

As the third activity Peffers et al. (2007, p. 55) propose creating the artifact after problems and objectives have been defined. They characterize the design and development activity as the focus of DSR. They describe the activity to involve defining the artifact's intended use and structure before finally creating it. Knowledge of theory, that can be applied to the solution is required for this activity according to Peffers et al. (2007, p. 55).

In this research the DSR artifact is a method, as in actionable guidelines. This method should include something that contributes to research to be considered a DSR artifact (Peffers et al., 2007, p. 55). The design and development in this thesis involve knowledge gathered from literature as well as qualitative knowledge gathered from the application environment. Qualitative knowledge is gathered via observation and interviews. The data is analyzed to understand the context and users (Morschheuser et al., 2018, pp. 15–16). The knowledge is usable in the artifact's design. The data collection and analysis methods are further explained in Chapter 4.4. The artifact's guidelines are summarized as design principles according to the design principle schema defined by Gregor et al. (2020, p. 1633).

4.3.4 Demonstration

Demonstration is the fourth activity in the process sequence by Peffers et al. (2007, p. 55). They recommend demonstrating how the developed artifact might solve the defined problems. They determine that knowledge of the ways the artifact can be used for problem-solving is necessary for demonstration. The proposed artifact in this research is demonstrated as a proof-of-concept. It includes mock-ups of a gamified MES, illustrating the design principles of how a gamified MES should be designed, as is the research question for this research. Mock-ups are part of technical documentation, usually done at the beginning of a project (Emond & Steins, 2011, p. 90). The demonstration is assessed by the case company and discussed accordingly.

4.3.5 Evaluation and communication

The fifth activity in the DSRM process sequence Peffers et al. (2007, p. 56) is evaluation, which involves reflecting the defined objectives to measured results that come from using the demonstrated artifact. They define this activity as requiring assessment and analysis practices. Despite being part of the DSRM process, evaluation is out of scope of this thesis, because it would require a longer-term review. It presents future research or work to be done at the case company.

Peffers et al. (2007, p. 56) end their process sequence with communication, the sixth activity. They recommend communicating accomplished research to pertinent stakeholders. This thesis constitutes communication of the accomplished research. Therefore, no separate reports are made.

4.4 Qualitative research approach

Juhila (n.d.-b) defines qualitative research as having characteristic features such as suspicion of the obvious, preference for qualitative, natural, and unstructured material, as well commitment to close-by study among others. This research reflects these characteristics, as obvious solutions are not applied without close examination of the target environment. Such examination is for example ethnographic research, which focuses on the studying of context (Myers, 2019, p. 112). Context is important for gamification (Helmefalk, 2019, p. 6), and analyzing it is part of designing gamification (Morschheuser et al., 2018, p. 15).

The qualitative research in this thesis is more akin to short-term ethnography (Pink & Morgan, 2013, p. 355) or focused ethnography, whereby field visits are shorter term, focused instead of open, and intensive on data analysis instead of experimentality (Knoblauch, 2005, p. 7). Ethnography tends to be a “long-term research process”, but it is not necessarily so in the case of design research (Pink & Morgan, 2013, p. 352). Therefore, short-term visits for observations combined with interviews are appropriate for this design research. For purposes of this research, qualitative methodology is applied as needed, as to not be characterized as the main methodology. The main methodology of this thesis is DSRM, with qualitative knowledge to support design and development of the artifact.

4.4.1 Data gathering

In this thesis, qualitative data is gathered via observation and semi-structured interviews. Observation is one method of conducting fieldwork and gathering qualitative data. It is insufficient as the only method of gathering data, as it makes analysis demanding (Tuomi & Sarajärvi, 2018, p. 69). Therefore, combining observation with other methods such as interviews is beneficial (Aarnos, 2018, p. 149), as it can result in new knowledge that would have been unobtainable via only interviews (Myers, 2019, p. 168). The combination of fieldwork and interviews is also recommended by Kumar (2013, p. 37). She considers them to be appropriate ways to collect data for player personas, which are used to portray users in this research. By not only observing activities, but participating in the activity while observing, the researcher can gain understanding of the experiences of the observed (Myers, 2019, p. 169).

This thesis approaches fieldwork by fragmenting the situations that are to be observed. Fieldwork such as observation is comprised of social situations, which are complex. Spradley (1980, p. 78) supports capturing the complexity of social situations by outlining nine dimensions a researcher should pay attention to. The nine dimensions of social situations a researcher should note are formulated by Spradley (1980, p. 78) as:

1. *Space*: the physical place or places
2. *Actor*: the people involved
3. *Activity*: a set of related acts people do
4. *Object*: the physical things that are present
5. *Act*: single actions that people do
6. *Event*: a set of related activities that people carry out
7. *Time*: the sequencing that takes place over time
8. *Goal*: the things people are trying to accomplish
9. *Feeling*: the emotions felt and expressed

The dimensions are to be used as support for the researcher in the field when asking questions and observing. Fieldwork should be concluded when no new observations are made and there is enough data to answer the research questions (Myers, 2019, p. 175) or field notes start repeating (Esterberg, 2002, p. 79).

Observation for this research is executed onsite at the business and on the workshop floor. The observations take place during the morning shift, for about 4 hours total. They begin with what Spradley (1980, p. 77) describes as a grand tour observation, where the main features of the business and their shop floor are introduced to the researcher by the case company representative. From there focus is directed towards the assembly cell where employees use MES in the assembly process. This is what Spradley (1980, p. 79) describes as a mini-tour, where questions focus on observations in a smaller space. Questions during the observations draw on the nine dimensions of social situations described by Spradley (1980, p. 78).

Field notes are the primary data gathered while observing on site because of corporate privacy matters. Taking pictures or recording is not allowed on the factory floor. Field notes are an important part of observation, and specific terms should be noted word for word, to not misrepresent the observed reality (Spradley, 1980, p. 67). As much as possible is included in the field notes such as “feelings, initial impressions, half ideas, possible leads, even admissions of tactical error or things missed during the day” because the researcher might find relevance in them later (Payne & Payne, 2004, p. 168). The field notes are written during the field visit, during breaks, and after the field visit.

The field notes are written using a smartphone, on a document with the nine dimensions (Spradley, 1980, p. 78) listed and supporting questions prepared beforehand. Any notes directly relating to the dimensions are written under the dimension topic, with continuous notes on observations written as they are discovered. Field notes are recorded as bulleted lists, with indented lists for further information on a certain note. The resulting notes after post-reflection are nine pages long and 1300 words.

Interviews are conducted in this thesis for further user analysis in addition to observation. This is because they allow us to “focus on the subject’s world” (Myers, 2019, p. 145), making it suitable for purposes of user analysis. As this thesis focuses on what gamification can offer the employees, it is imperative to listen to them, whom the artifact concerns the most. The interviews are planned to be semi-structured, as in having some prepared questions, without restricting new questions emerging during the interviews (Myers, 2019, p. 150).

The interviews are recorded and conducted in a conference room near the observed factory floor, where the workers often convene. They are held in Finnish and planned for

45 minutes each. Six people were interviewed. The interviewees are selected by the case company. They are chosen because of their varying positions and experience, whereby they represent a cross-section of employees working in and around the shop floor. Two senior employees speak on behalf of a wider group, like a team in a cell that they oversee. Three assembly workers speak on behalf of themselves, with work experience ranging from a year to over ten years in multiple assembly work positions. One interviewee works as a support for the factory floor operations. The variation in position and work experience allows for broad examination, meanwhile the semi-structured format of the interviews allows for deeper exploration into the esoteric characteristics of the interviewees as employees and users.

The semi-structured interviews have questions pertaining to the themes prepared in advance, following the player persona model (Figure 5). The predetermined themes are interests, goals, aspirations, pain points, and work culture. Questions regarding Bartle's player type (Bartle, 1996) are excluded from interviews, because of time constraints and difficulty of implementing them in this context. Such questions need a separate survey to be conducted.

Myers and Newman's (2007) dramaturgical model and recommendations for qualitative interviews are used to plan the interviews. Their model supposes that qualitative interviews are like dramas, and thus have concepts of the stage, the actor, the audience, the script, entry, and exit, which altogether make up the performance. They suggest seven guidelines for the interviewer based on the forementioned concepts. They encompass important considerations for interviews, which is why each guideline is considered for this thesis.

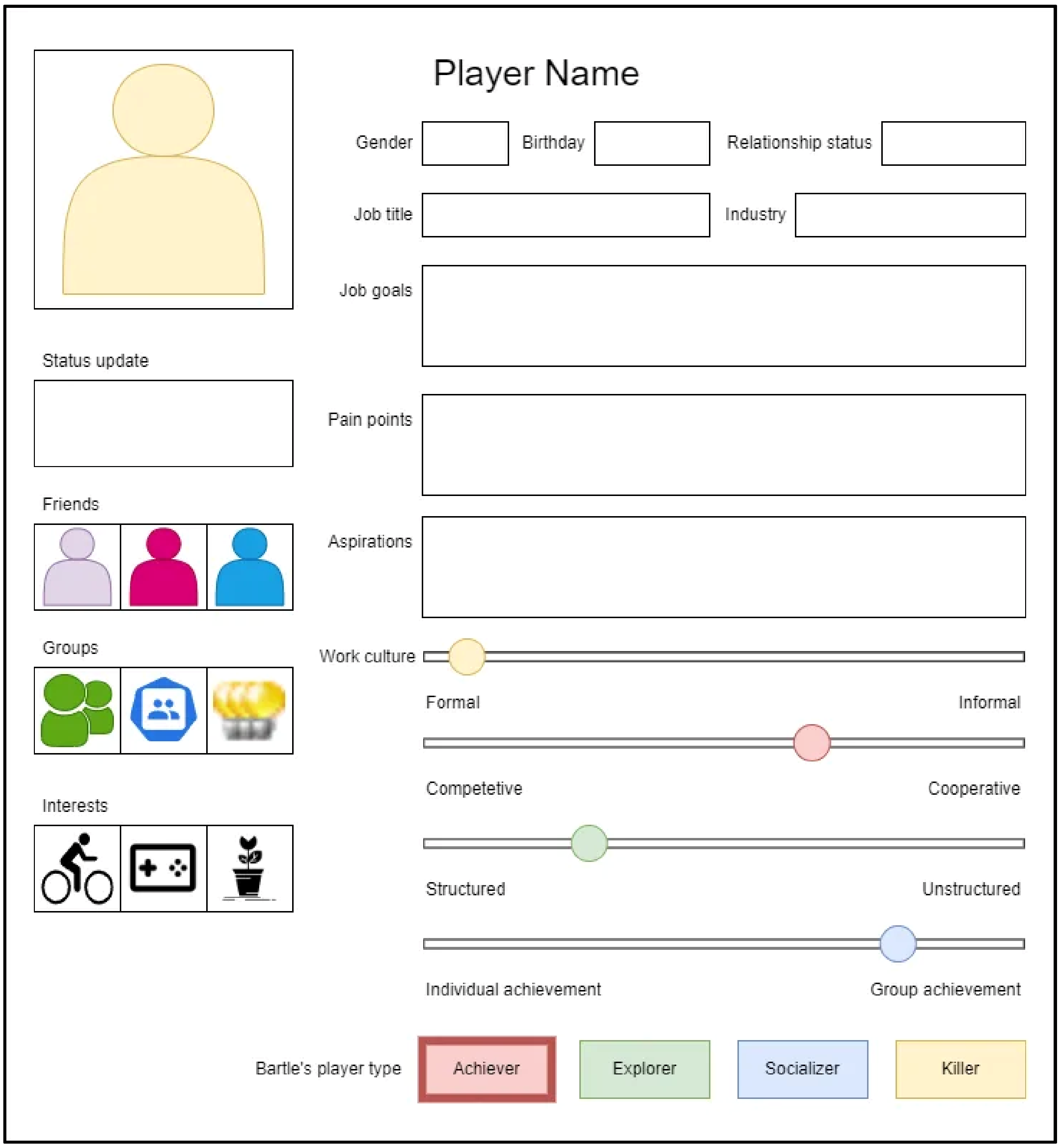

Figure 5. Player persona template (Kumar, 2013, p. 46).

Firstly Myers and Newman (2007, p. 16) advise interviewers to situate the interviewer as an actor in the drama. The interviewer is the author of this thesis, a student of information systems, in the role of the master thesis writer. It is important to note that the interviewer differs from the interviewees, as they do not have experience in the field, have an academic background, and are somewhat younger. The interviewer and interviewees do not have any prior work or personal relationships, establishing a neutral ground for the interview. Additionally, they share a common language and nationality.

Secondly Myers and Newman (2007, p. 16–17) advise minimizing anything that might make the interviewee uncomfortable. Therefore, interviews are conducted face-to-face at the onsite facilities to avoid any issues that may arise from video conferencing. This is particularly important for shop-floor assembly workers who are characterized by their work being onsite and face-to-face. In contrast, this consideration would not be necessary for office workers. Myers and Newman (2007, p. 16-17) suggest that interviewers should dress and speak appropriately to establish rapport with interviewees. This involves wearing company clothing and using shop floor jargon, including the multiple nicknames employees use for their MES, products, and components.

Thirdly, Myers and Newman (2007, p. 17) recommend variety in interviewees to avoid bias. The interviewees are selected for their variety in use of MES, work experience, and position. They are mostly shop floor workers, as the reason for interviewing is user analysis. Fourthly, they remind that "everyone is an interpreter". For the assembly workers, interviews are rare, which affects the interview as the "actors" are not well-versed in "acting". Interviewees will interpret questions and the interviewer will interpret answers to the best of their ability.

Myers and Newman (2007, p. 17) in their fifth guideline recommend "mirroring", as in using the interviewees language when asking questions. The semi-structured nature of the interviews allows for mirroring, as questions are not restricted to the initially planned ones. In the sixth guideline they recommend flexibility in the interviews on the part of the interviewer. This guideline supports the decision to do semi-structured interviewing in this research.

The seventh and last guideline concerns the ethics of interviewing (Myers & Newman, 2007, p. 23). To ensure ethical standards are being followed, permission is obtained, respect given to interviewees for their effort, and ensuring commitments are fulfilled. Permission is acquired before the interview is officially on the "front stage" being executed and recorded, via informed consent and signing of a privacy notice. Assembly work is scheduled work often under time pressure, which is one of the many reasons that the interviewees are to be respected and thanked for. Commitments to the commissioning companies, and the security and confidentiality of transcripts and knowledge acquired from the interviews are to be held. By the end, the interviewee is asked if they have recommendations for subsequent interviewees as recommended by Myers and Newman (2007, p. 15).

4.4.2 Data analysis

The qualitative data gathered is analyzed with the intent to understand the user and their context. Kumar (2013, p. 35) recommends designers of gamification to know the player, which is in line with the need for user analysis (Morschheuser et al., 2018, p. 15). User analysis is aimed at forming a player persona, as well as looking for other emerging themes that support the design of the artifact. Player personas are fictive representations of target users' aspects, including for instance job title, job goals, pain points, aspirations, groups, and interests. A player persona template to be used is shown in Figure 5. As for the context analysis, Klevers et al. (2016, p. 4) emphasize the importance of analyzing the basic conditions of a business process, to understand where gamification can be applied in the business process without disrupting it. In this research, the business process is a manufacturing process which consists of assembly tasks. Analysis thereby intends to identify where in this context gamification does not disrupt assembly work or other tasks an employee must fulfill during the process.

The analysis of qualitative data in this thesis is theory-driven, as in based on theory but not limited by it, therefore new categories can emerge from the data (Tuomi & Sarajärvi, 2018, p. 81). The two initial main topics of analysis are context and users, because understanding them is needed for designing gamification (Morschheuser et al., 2018, p. 9) and thus, the objective of this qualitative analysis. Context analysis is categorized according to the nine dimensions of social situations by Spradley (1980, p. 78) explained in chapter 4.4.1. User analysis aims at defining a single player persona (Figure 5). Therefore, analysis intends to define general user characteristics as well as sub-themes for the themes predetermined by the player persona model (Figure 5). The general user characteristics to be defined regard age, gender, IT-skills, industry, and professional title, The themes, for which sub-themes are to be defined, are interests, goals, aspirations, pain points. They are analyzed by gathering data points and grouping them in clusters around a certain emerging theme, which constitutes the sub-theme in thematic maps. Analysis includes initial thematic maps, but only the further refined developed thematic maps are introduced in this research reporting. Thematic maps are visual representations of relationships between themes and sub-themes, which can be refined from initial to developed maps, whereby some data can form main themes and some fall off (Braun & Clarke, 2006, pp. 19–20).

Work culture is analyzed by defining where the culture is weighted towards on its four dimensions. The dimensions of work culture include the dichotomies of formal vs. informal, competitive vs. cooperative, structured vs. unstructured, and individual vs. group achievement. Data points regarding work culture are situated on a scale, whereby an expression like "I prefer to work together" is placed towards the cooperative end of the scale. The scales are further analyzed to infer where the culture is situated on the player persona (Figure 5).

The analysis of the general user characteristics, thematic maps, and work culture analysis inform the design of the player persona (Figure 5). Other knowledge usable for the design of the artifact that emerges from interviews is analyzed and described accordingly. The thematic maps are introduced during the design and development of the artifact, within Chapters 5.3.1 and 5.3.2 in Figures 6–8. Because of the new and interesting ideas presented by the interviewees, which are iteratively discussed with other interviewees, new knowledge describing user motivation and opinions on certain features emerges, as well as further information on the context.

5 Designing gamification guidelines for a MES

This chapter presents the process of designing guidelines for gamifying a MES. The process follows the DSRM process sequence overview outlined in Table 5, as per the DSRM process model (Figure 4), even though the research entry point is objective-centered. Further explanations are provided for each activity of the process sequence as they apply to this thesis.

Table 5. DSRM process sequence applied.

DSRM Process activity	Application to this research
Problem identification and motivation	Identifies the problem of providing feedback in systems, which employees appreciate. Prior literature is insufficient to decide how to gamify a MES. Literature calls for further research on gamification at work and in manufacturing. Demographic changes motivate the importance of a solution in literature.
Objectives of a solution, Research Entry Point	Objective-centered solution, defined as developing guidelines for gamifying a MES. In addition, improving the human-centered design of the system in accordance with the Industry 5.0 transformation.
Design and development	Describes the process of designing guidelines for gamifying a MES, based on knowledge of context, users, and literature. The guidelines are summarized as six design principles.
Demonstration	Demonstrates the feasibility of the guidelines and design principles through eleven proof-of-concept mock-ups. They are illustrated examples of how a gamified MES could appear.

The problem definition that the artifact intends to solve, as well as the solution's importance is introduced first in Chapter 5.1. Then the defined objectives of the solution are introduced in 5.2. After the problems are identified and the objectives for the solution are set, research proceeds to discuss the process of design and development of the artifact in Chapter 5.3. The design is based on rigor established in the literature review in Chapters 2 and 3, and relevance established in the problem identification (Chapter 5.1), objective identification (Chapter 5.2). The context (Chapter 5.3.1) and user analysis (Chapter 5.3.2) are used to form the player persona (Chapter 5.3.3). Guidelines based on these forms of analysis are summed up as design principles. In other words, the current knowledge base, application environment and user characteristics inform the development of the artifact. Lastly, the artifact is demonstrated via wireframe mock-ups (Chapter 5.4), which constitute the proof-of-concept for the developed artifact's feasibility. Feedback on the demonstration is received from the case company and discussed lastly after all the mock-ups are introduced.

5.1 Problem identification

This thesis identifies the problem based on the case company's understanding of its current state presented in private report of a survey (personal communication, October 12, 2023). Prior literature is insufficient to support the use of gamification in MES, instead providing guidelines (Keepers, Nesbit, & Wuest, 2022; Klevers et al., 2016; Korn, 2023; Kumar, 2013; Morschheuser et al., 2018; Ulmer et al., 2020). The literature motivates the need for further research into GfM (Keepers, Nesbit, Romero, et al., 2022) and gamification from employee perspectives (Wallius et al., 2021). Nevertheless, the literature provides reasoning for the application of gamification in manufacturing (Chou, 2019; Korn, 2023).

The case company has conducted a survey on IT system data and feedback and documented in a private report (personal communication, October 12, 2023). The report presents an overview of the data that employees find useful, including feedback, end-product information, and production progress. Additionally, it highlights that some employees prefer personal feedback while others prefer team feedback on performance. Overall, comprehensive feedback is preferred. The case company faces a challenge in providing visualized feedback within their systems. They aim to enhance the user experience (UI/UX) but are uncertain about the starting point.

Prior literature on gamification in manufacturing is not suitable as such for the case company to decide how to gamify their systems. Further research into how gamification can be applied to a MES is needed. Practices by for example Morschheuser et al. (2018), Kumar (2013), and Klevers et al. (2016) inform the designing of gamification, but they stay at a general level. Guidelines by Keepers, Nesbit, and Wuest (2022), Korn (2023), and Ulmer et al. (2020) are closer to the context in this study. Nonetheless, need for further research is defined by, for example Keepers, Nesbit, and Wuest (2022, p. 460), who call for more research into the characteristics of production systems and the involved operators. Likewise Wallius et al. (2021, p. 132) encourage more research into employee perspectives. Thus, this thesis delves deeper into the characteristics of one production system, MES, through the perspective of the assembler employees.

The reasons for providing gamification in manufacturing are noted in the literature review. For example, the generations entering working life are accustomed to engaging design, and thus have different expectations for information system designs compared to previous generations before widespread digitalization (Korn, 2023, p. 252). These generations are accustomed to systems that provide meaning and autonomy, which gamification can offer to otherwise function-focused systems (Chou, 2019, pp. 58–59). Furthermore, research on GfM has shown a positive trend from 2019 to 2021 (Keepers, Nesbit, Romero, et al., 2022, p. 313). Therefore, gamification is considered relevant for manufacturing companies, and its applicability to systems such as MESs should be evaluated.

5.2 Objectives of the solution

The objective of this research is to develop a gamification method for MES. In other words, to provide guidelines on how to provide gamification in MESs. The objective includes coming up with ways to give feedback to the user, which was a need identified in the intra-company survey (personal communication, October 12, 2023). The guidelines are developed on a general level, meaning they can be applied to other companies in manufacturing contexts. The guidelines aim to give guidance on the specific system context of MES that is used in manufacturing, as more focused research on different applications has been called for (Keepers, Nesbit, Romero, et al., 2022, p. 314). MES is chosen as the system to focus on, because it is the main system that manages assembly work and control of production. Research scope for this thesis is limited to the part of a MES that the assembly workers can access.

The instantiation of the artifact is intended to be used by employees of the case company, as they work with the MES, to provide them feedback and possibly increase engagement at the workplace. This thesis limits the scope to design, which is intended to inform implementation, should the case company or other companies go forward with gamifying their MES.

The research takes an objective-oriented approach due to the industry's need to adapt systems to accommodate human needs. The manufacturing industry is experiencing transformational change with the Industry 5.0 approach. The case company that has commissioned this thesis and its cooperating partner company are in joint Industry 5.0 initiative. One of the aims of Industry 5.0 is to prioritize the well-being of humans (Leng et al., 2022). As a result of the need for human-centricity brought about by the Industry 5.0 transformation, companies' systems need to be adapted to better include humans. The objective requires summarizing prior knowledge and then applying it to the manufacturing context, with the aim of producing human-centered designs.

5.3 Design and development of the artifact

The design of the artifact bases itself on practices and methods identified in the literature review, as well as the results of context and user analysis. As suggested by Morschheuser et al. (2018, pp. 14–16) user and context analysis should be conducted before moving on to ideation and design. During the analysis phase (see Table 2), the first design principle (see Table 1) of comprehending user needs, motivation, and behavior, as well as the context, should be applied. This phase requires a comprehensive analysis of the system's operational context and target users. To achieve this, qualitative methods such as observations and interviews are applied in this thesis. The aim of context analysis is to comprehend the nine dimensions of social situations (Spradley, 1980, p. 78) in which the employees work, as well as their use of MES. Analyzing the nine dimensions provides a holistic understanding of the context. Therefore, the artifact can be designed to better fit the context. The aim of user analysis is to create user types by describing their characteristics such as age, gender, activities, job level, motivation and preferences (Morschheuser et al., 2018, p. 15). This is accomplished in this chapter by defining a player persona (Kumar, 2013, p. 46). Thus, the design of the artifact can be tailored to better suit the users.

The design and development of the artifact bases itself on practices and methods identified in the literature review (Chapters 2 & 3), as well as the results of user and context analysis introduced in this chapter. The design principles and their underlying guidelines are introduced last in this chapter. The design principles attempt to answer the research question set for this thesis: how should a gamified MES be designed?

5.3.1 Results of context analysis

The application environment is described based on Spradley's (1980, p. 78) nine dimensions of social situations, as outlined in chapter 4.4.1. The descriptions of the context's dimensions for this research are derived from observations conducted on the shop floor of the case company's factory. Further information about the context was obtained from the analysis of interviews regarding the current state of MES, its features, and its usage.

The results of context analysis are summed up in Table 6, with the dimensions and observations regarding them. The context analysis adds to the knowledge base of literature review and user analysis. This analysis therefore informs the design of the artifact and can be used to create guidelines that account for the context.

Table 6. Dimensions and observations as results of context analysis.

Dimension	Observations
The space	Multiple facilities, with focus on one large factory's shop floor hall, which has manufacturing in cells, sub-assembly areas, and lines.
The actor	Multiple general teams for cells and line-stations, separate specialized teams. Personal accounts are used to log into the MES.
The activity	Teams assemble products with different configurations from an unfinished pre-assembled product to testing-ready, in cells or lines with hundreds of activities.
The object	Fixed in place computers for each station, whereby the MES is used everywhere on factory floor, with slow systems and varying use.
The act	List of phases with activities being the smallest units of action in MES. Smaller acts such as for single parts are described elsewhere.
The event and time	Events are time-bound and lead-time depends on the product and station. Phases have planned durations, but activities are not comparable.
The goal and feeling	Work is goal driven. Inability to perform work and system's hinderances lead to negative emotion. Noticeable sense of community.

The space: the physical place of the shop floor

Observation is conducted in one facility with a focus on assembly cells. Other facilities and different modes of assembly such as lines are excluded from observations because of time constraints. Furthermore, focus is put on assembly cells inside the facility. As stated in Chapter 4.4.1, a grand tour of the whole facility's shop floor was generally introduced, and a mini-tour focused on assembly cells. The shop floor is in one large factory hall. The facility's floor is comprised of assembly cell areas, sub-assembly areas, and traditional production lines. The case company manufactures multiple different products with variations in configurations. The cells have areas for components nearby.

The actor: the people involved

Each assembly cell has a team assigned to it. Teams have less than ten people assigned to them. The team members are present at different times on different shifts. One team mainly works in one cell. The team can switch which cell they are working in. People at the factory floor are primarily males. The floor has employees from multiple employers, but there is in practice no distinction made between them. In addition to general teams for the cells, there are some specialized teams that move between cells, applying their expertise where needed. Everyone on the floor has a personal account that is used for the computers on the floor. The team layout can be distinguished as multiple general assembly teams, and separate specialized teams.

The activity: sets of related acts people do

The analysis of “The Activity” in Spradley's (1980, p. 78) nine dimensions of social situations differs from the recognizable activities that are marked as completed in the MES. The teams in the observed cells assemble products from an unfinished pre-assembled product to a product ready for testing and inspection It is important to note that this observation does not include analysis of the testing, inspection, or line assembly activities. However, the MES is used for all activities on the shop floor. The observed cells have fewer than ten manufacturing phases, with each product undergoing hundreds of activities throughout these phases. The phases contain activities, which are listed discretely, such as “assembly of component A to B”. The number of phases and their activities vary depending on the product configuration. Each cell has its own product under assembly. The specialized team completes activities for all cells, furthering the assembly progress for the specific cell they are working on. Therefore, the specialized team completes some activities instead of the team assigned to the cell.

The object: the physical things present

Observation focuses intensively on the object dimension, because of the research focus in this thesis being on the MES. The main application of interest, the MES, resides within the computers on the shop floor. The area where the objects are, and most importantly the MES, is closely observed.

The computer, parts, and other accessories necessary for manufacturing are on the ground level. The product under manufacturing is on a separate level in the observed cells. There are stations with differing layouts. Each station, be it cell or line, has a screen with information about the product under manufacturing. The information includes the product’s configuration, serial number, destination and the end product’s use, and the person in charge. The screens do not show, for example, progress indicators. The manufacturing cells handle a lot of material, likewise with other stations, some of which must be scanned separately into the system.

The current system for which gamification elements are to be implemented is a Manufacturing Execution System. The system is used by teams on the manufacturing floor of each of the manufacturing facilities. The system that houses the MES is used by every station on the manufacturing floor. The MES is mainly accessed from computers installed next to each station in the manufacturing process. Each station, such as the assembly cell, has a discrete computer that can access MES. In other words, the application environment is characterized by computers fixed in place instead of handheld devices or other means of access. Users navigate multiple screens to find their work in, for example one of the production cells. The MES provides information to the assembly workers about activities (as in assembly tasks), disruptions, instructions, and material calls. Using the MES, users can navigate to other stations, not just cells, and see their progress.

One person at a time interacts with the activity list, sometimes marking them as done immediately after activity completion, sometimes after multiple activities have been completed. This means that activities completed cannot be straightforwardly connected to a single person. This inaccuracy in connecting completed activities to discrete users might be a challenge for gamification for single users. Because for example to provide a feature for individuals to gather badges for completed work, the individual's data must be possible to connect to the individual's actions. Employees who complete required work, but never mark activities as done on their own accounts, will not achieve badges.

Context analysis primarily relies on data from observations, supplemented by findings from interview analysis. The interviews provided insights into the current state of the MES, encompassing its functionalities, user feedback, and usage patterns. Analysis Examination revealed deficiencies in user feedback within the MES, contradicting the acknowledged importance of feedback within the case company's IT systems, as indicated by the company survey (personal communication, October 12, 2023). Issues related to incomplete or absent product assembly drawings were highlighted as particularly significant because newer employees heavily rely on these instructions. Moreover, younger employees exhibit a greater inclination towards MES usage compared to their older counterparts. Notably, a desire for a login-free mobile -application was expressed. Furthermore, dissatisfaction surfaced regarding system slowness and login delays due to account data loading each time.

Additionally, collective responsibility for activity completion was identified. Activities are marked completed as a team, meaning that workers do not always mark completion on activities they have personally completed. The teams are together responsible for activity completion because they are responsible for the product under assembly in the cell. The MES has had an update to the UI recently. It is possible to switch between the old UI and the new updated UI. Some prefer the old UI, which has for instance fewer visual elements and less information grouping compared to the new updated UI. The new UI enables starting and ending the activity, as well as “traffic lights” indicating progress on activities. Some like the new UI and think that the lights were a good feature. The new UI is however more suitable for gamification because of its information grouping and streamlined visual elements.

The act: single actions that people do

The act refers to the single actions performed by people. This dimension recognizes smaller units of action than activities which are sets of related actions in Spradley's (1980, p. 78) nine dimensions of social situations. To avoid confusion, analysis of “The Activity” is separate from the activities in MES. The MES involves activities, and assembly work is characterized by the list of activities inherent in each assembly phase of the product. The MES lists each activity as the smallest distinguishable action performed by individuals. Some MES activities may consist of multiple actions that are not differentiated in the activity list. Product drawings provide details on smaller actions, such as the selection of individual parts.

The event and the time: sets of related activities, and their sequence over time

The event and time observations are combined because of the similarity in findings. The events are time-bound in this context. The lead-time for assembly depends on the product along with the assembly stations characteristics, layout, and location. Currently phases have comparable planned durations, meaning that each phase should be completed in the same amount of time. However, the activities within the phases are not comparable, with some activities taking minutes and some taking hours to a day. In the case of pre-assembly and sub-assembly areas, the time that phases and activities take varies less than in stations such as the cells. This inequality in activity completion time can affect the design of gamification. For example, competitive elements can be difficult to design because the work is not comparable. Comparing for example elapsed completion time for phases can be difficult if the time required for activities or phases varies significantly.

The goal and the feeling: the things people are trying to accomplish, and emotions felt

The observations on the goal and feeling are combined as well, because of the similarity in findings. Emotions felt are bound to goals, as the work is goal driven. The inability to work toward the goals results in negative emotion. During observations, no goals other than planned lead-times were identified. The assembly workers are intrinsically driven as they want to carry out their tasks, and nobody wants to be there needlessly. If production stalls for an anticipated longer time, workers are assigned to different parts of the factory. The workers are focused on functionality, as they want things to work as well and as fast as possible. Frustration is felt in supporting structures that slow the assembly work. Supporting structures that frustrate are for example information systems' UI changing, multiple logins to different systems, incomplete instructions, and parts not being in the order of assembly. A general atmosphere of camaraderie and sense of community was noticed when observing.

5.3.2 Results of user analysis

The results of user analysis are presented by first describing the general user characteristics, then the predetermined themes, as well as work culture analysis, and finally discussing the emerging knowledge before moving on to the description of the player persona. The user analysis is aimed at on configuring a player persona based on the template in Figure 5 via characteristics and themes. Therefore, the general user characteristics and the themes for analysis are predetermined because they relate to the persona. The analysis on the general user characteristics aims at describing users' age, gender, IT-skills, and professional title. The analysis based on the predetermined themes aim at describing users' goals, pain points, aspirations, and dimensions of work culture. Additionally, new knowledge emerged from data analysis, which describes motivation and opinions on certain features.

The resulting general user characteristics define the average age of the users as between 30 to 50. The users' IT-skills in general at work or off-work focus on mobile technology, with sparser use of PCs. This research represents the user analysis of assemblers in manufacturing cells. Therefore, the professional title is assemblers, with a focus on those working in manufacturing cells.

Analysis based on the predetermined themes is crucial for the creation of the persona in Figure 13. The resulting sub-themes under the predetermined themes of interests, goals, aspirations, and pain points in Table 7 directly inform the player persona defined in Figure 13.

Table 7. Predetermined themes and sub-themes.

Predetermined themes	**Sub-themes**
Interests	Crafts, recreation, exercise, friends & family
Goals	Quality workmanship, timeliness, and learning to succeed
Aspirations	Competence development, soft peer leadership, and contentment.
Pain points	Momentary problems, work hinderances, slow system which lack in use.
Motivation	Salary, features of work, and community.

Work culture is analyzed separately by setting data points on predetermined scales, which indicate where the culture is weighted towards. Work culture gathered significant data to define where the users' work culture lies between the four scales of formal or informal, competitive or cooperative, structured or unstructured, and individual or group achievement. The culture is defined as mostly informal, tending towards cooperation, largely unstructured, and somewhat neutral in rewarding the group or the individual, with a slight tendency towards rewarding group achievement.

The emerging knowledge about motivation describes the employees as motivated by salary, features of work, and community. The knowledge about users' opinions on features describes what opinions users have on three discrete features. Knowledge about motivation and opinions on features is important because gamification design can gain from it.

The data can be extrapolated to depict a larger crowd than the interviewees, because observations feed into the analysis as well as interviewees including senior employees who could speak for the wider work community. Based on the data analysis, a general characterization of a manufacturing cell assembly worker is described, mentioned from here on as worker, for the sake of brevity.

General user characteristics

General user characteristics are needed to form the player persona (Kumar, 2013, p. 46). General characteristics of the users are described based on data analysis. These include information about age, gender, IT-skills, and professional title.

Analysis describes workers in their 30’s to 50’s, with 20’s and 40’s as outliers. All interviewed users are male, with observation reinforcing the fact that assembly workers are primarily males. Data suggests the users’ IT-use to focus on mobile technology. They generally use mostly mobile devices, compared to the sparse use of PCs. There is data contradicting this, where some are used to IT thoroughly. The industry in this thesis is decidedly manufacturing, because the case company operates in only one industry of manufacturing. It is worth noting that even though games are of interest in this research, gaming in free time is mentioned only once.

Based on this analysis, the player persona should be aged 30 to 50, male and a mobile IT user. Its professional title should be “Assembler”, more specifically an assembler who works primarily in manufacturing cells. This stems from data gathering and analysis focusing on the assembly cells and employees working in them.

Predetermined themes

The analysis according to the predetermined themes of workers’ goals, aspirations, and pain points at work resulted in the creation of three thematic maps, as shown in Figures 6–8. These maps are developed versions of initial maps formed during analysis. The data points are organized to form sub-themes related to each predetermined theme.

Specifically, the data points clustered around sub-themes such as timeliness in Figure 6 encapsulate detailed and noteworthy insights gathered during the interviews. These data points are presented in summary due to the interviews being conducted in Finnish. Therefore, any data points in quotation marks, such as “Quality is what we do” (Figure 6), are indirect quotes.

The analysis revealed three goals that workers have as shown in Figure 6: quality workmanship, timeliness, and a desire to learn to succeed. The workers aim to perform their work with high quality and avoid mistakes, which can be costly for the business. While timeliness is an internal goal for some workers, it is an external goal demanded by the business. Learning to succeed requires more than just learning itself; it involves using what is learned to achieve success in tasks.

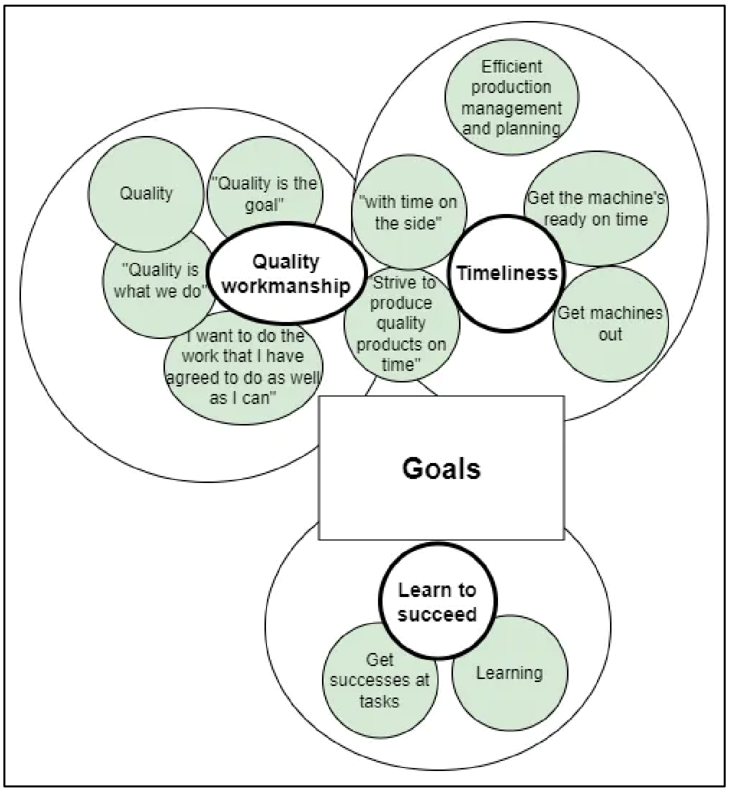

Figure 6. Thematic map of goals

Workers aspire for competence development, soft peer leadership, and contentment as shown in Figure 7. Workers were excited about competence development, as they want to learn, improve, be better at work, and take pride in their quality of work. The aspiration of soft peer leadership means that the workers do not aspire for actual career promotions, with the additional negative connotations towards office work. Contentment to the current position is an atypical aspiration, but the theme gathered notably many data points, as to be noteworthy. Data analysis describes workers generally liking where they are situated within the case company.

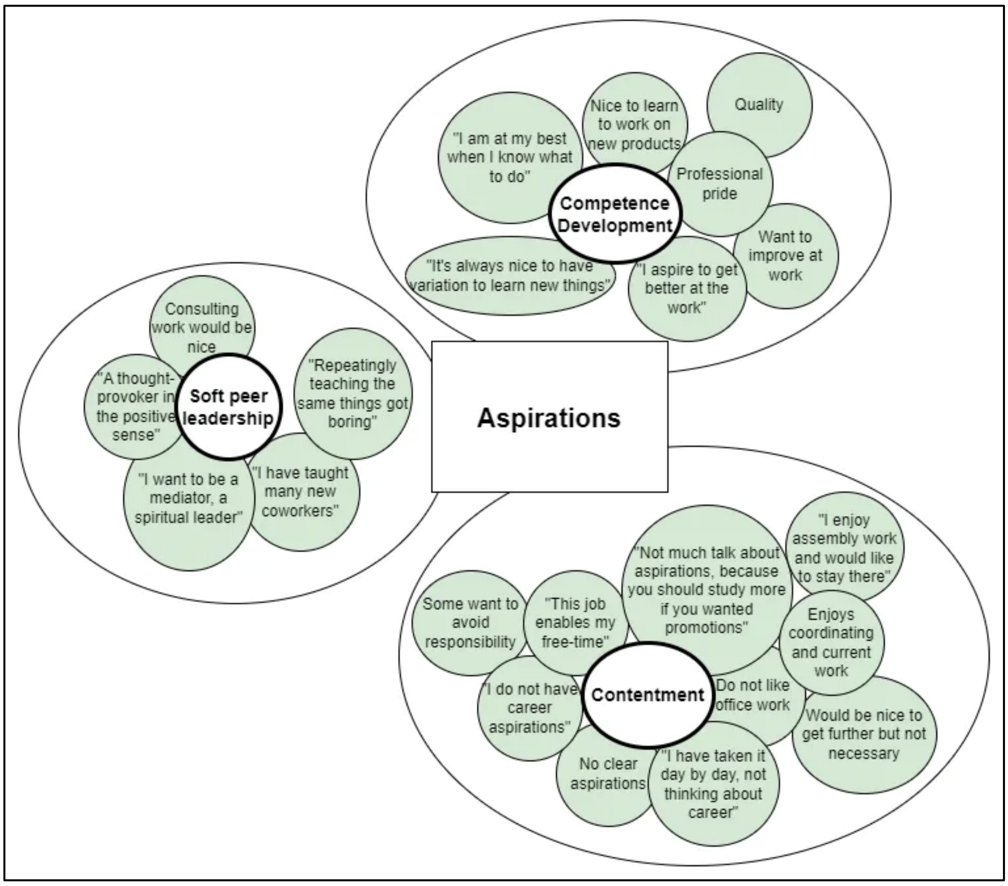

Figure 7. Thematic map of aspirations.

Sub-themes for pain points were identified as momentary problems, work hinderances, and slow systems that lack in use. The sub-themes and their underlying data points are shown in Figure 8. The first sub-theme describes momentary problems, which are unspecific in nature. For example, there are some unspecified unwanted activities or uncomfortable phases. This pain point depends on the case and cannot be concretized further. The data points regarding the second sub-theme of work hinderances describes workers facing problems when something interferes with or hinders work. For example, shortage of parts or hurry which interfere with work. The fourth sub-theme describes system slowness, lack of timely system usage, and forgetfulness. System slowness leads to diminishing use, which feeds in to for example workers not entering information on time.

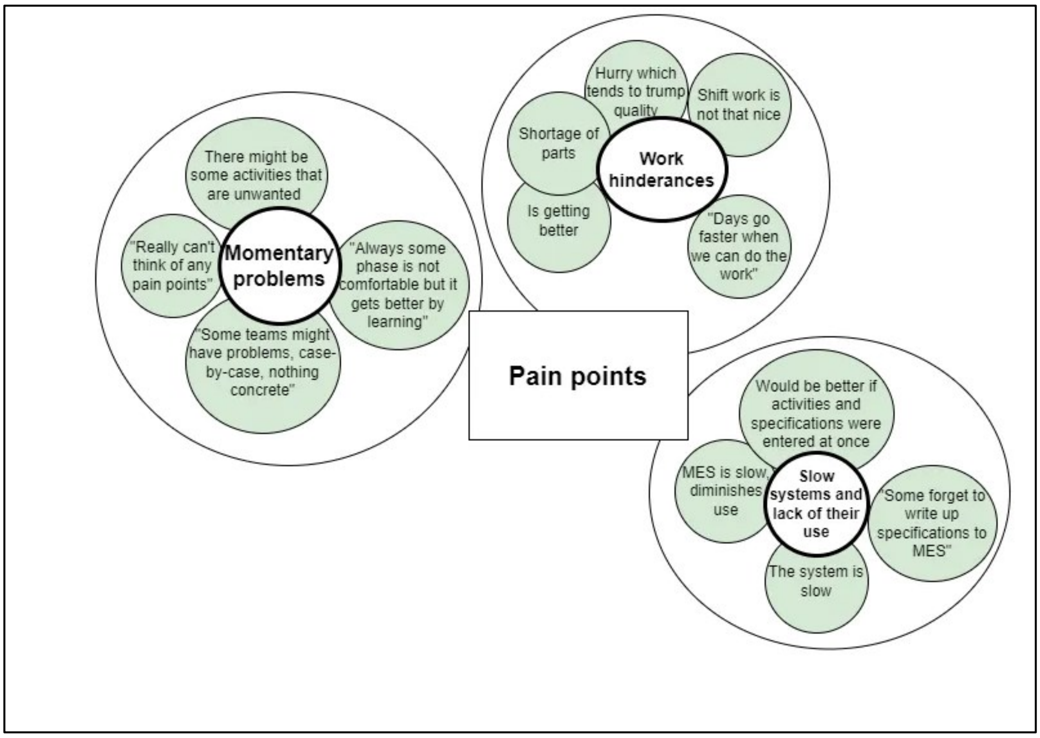

Figure 8. Thematic map of pain points.

The analysis of work culture intends to figure out where the culture the assemblers work in lies between the scales of formal or informal (Figure 9), competitive or cooperative (Figure 10), structured or unstructured (Figure 11), and individual or group achievement (Figure 12). This theme's four dimensions are analyzed by situating the data points on the four scales represented in the figures (9–12). All representations of the scales are the same in size. Each data point regarding work culture was put on a scale, depending on which way the meaning of the answer points to. Neutral data points were situated in the middle of the scale. For example, the data point of "lots of informal conversations" points to informality in the work environment, therefore it was put towards the informal end of the scale.

The first scale, formality of the culture, had the least data points. The work culture can be described as mostly informal because the data points situated in the formal end describe job training or a wish for the culture.

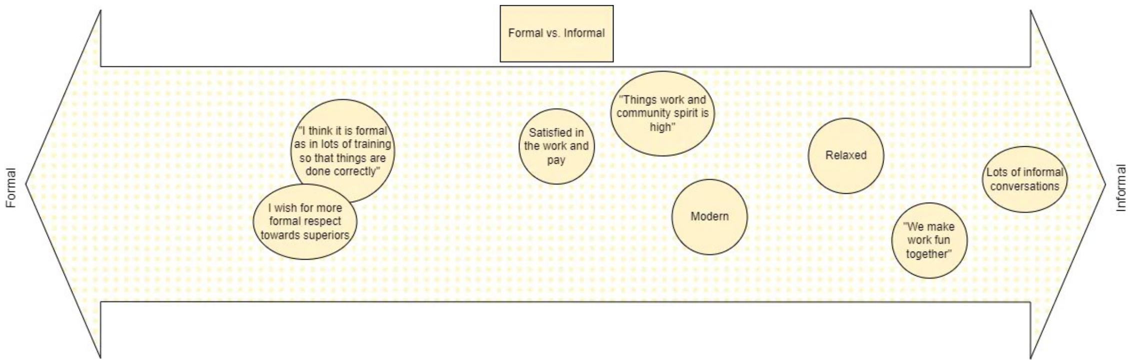

Figure 9. The scale of formality vs. informality in work culture.

The second scale of competitive vs. cooperative work culture gathered the most data points out of the four. The data points at the competitive end are inconclusive, as they describe other teams competing. Data points in the cooperative end also include strong expressions such as "competition between teams is bad", "we do not compete between team members" and "I do not think any competition is fitting in this field". For competition to be good, it is described as "playful" or between other companies. Data gives the general idea that the work culture regarding competition seems to differ between teams, as some data points refer to other teams in three data points: "some other teams compete", "some compete against other teams" and "50 percent compete, 50 percent cooperate". Because of the data's inconclusiveness in the competitive end and the strong expressions in the cooperative end, the culture therefore tends towards the cooperative end.

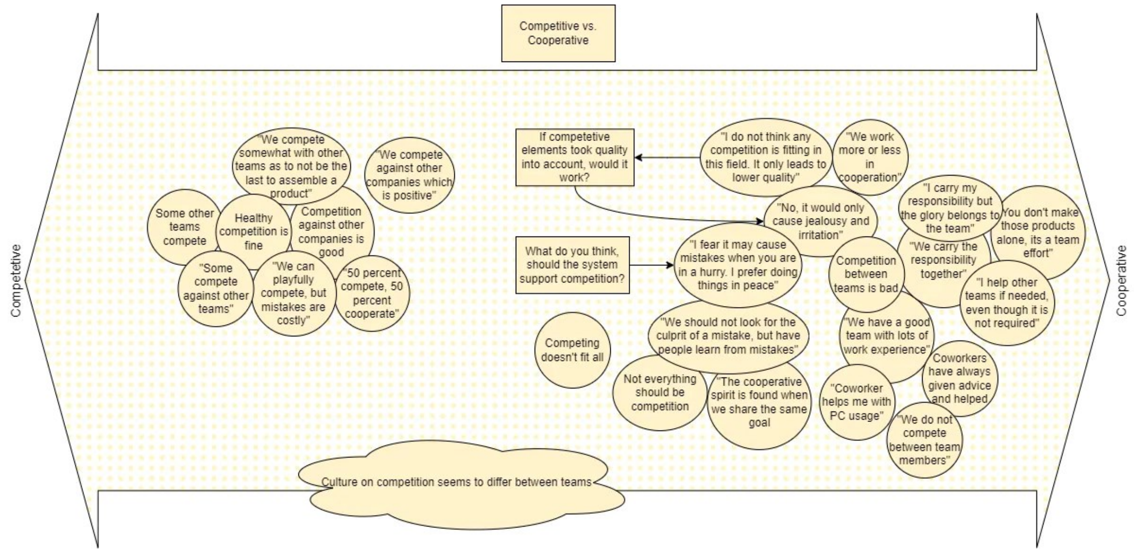

Figure 10. The scale of competitiveness vs. cooperativeness in work culture.

The work culture is certainly towards the unstructured end, as most data points are situated there in the third scale. The data points in this scale are the most unified out of the four categories. For example, twelve out of sixteen data points regarding the theme had to do with how the work can be executed as the workers see fit themselves or as a team. The only structure identified was the limitations concerning product structure. Because of the emphasis on the freedom of task execution, the culture leans towards the unstructured end.

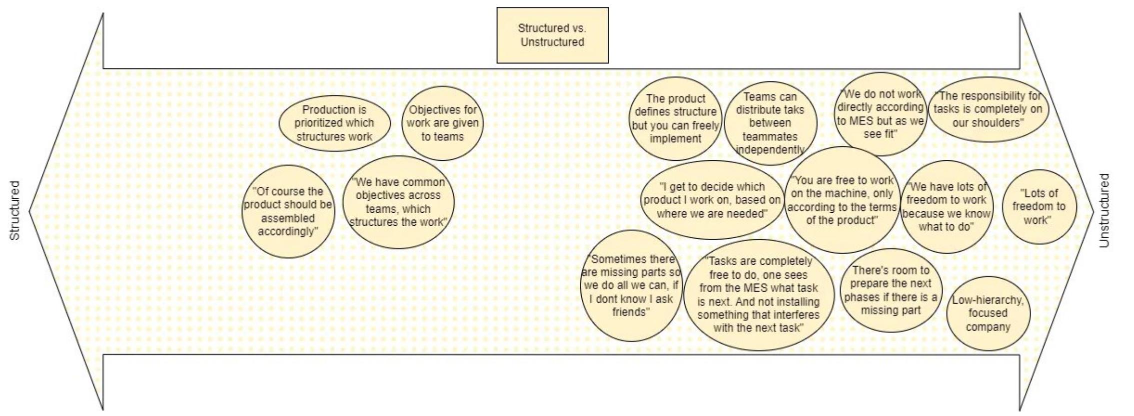

Figure 11. The scale of structured vs. unstructured work culture.

The last scale, whether the work culture is oriented towards individual achievement, or group achievement, is the most inconclusive and balanced out of the four scales. Inconclusive or neutral data points are situated in the middle of the scale. Some data points call for the need for rewarding, others say there is none, meanwhile some do not wish for rewarding at all. These answers are inconclusive as to whether achievements are rewarded to a group or to an individual. The answers often mentioning "us" and "we" situate many data points towards the group achievement end, such as "we work as a team and should be appreciated as a team" and "I would like getting rewarded, as a team, which would make us want to be more efficient". Some data points that are situated towards the individual achievement end concern minor rewards or days off. There are certainly data points indicating wishes for the culture, such as "there should be some goal orientation", "I would like getting rewarded...", and "I think milestones should be noted". The inconclusive and neutral nature of the data situates the culture somewhere in the middle of the scale.

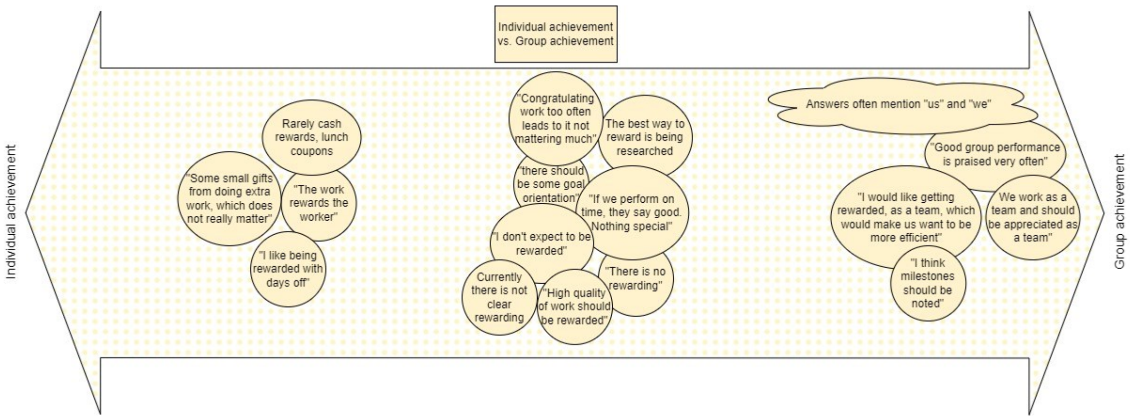

Figure 12. The scale of individual achievement vs. group achievement in work culture

Emerging knowledge

Data analysis resulted in emerging knowledge about user motivation and opinions on certain features. They are a result of analysis on conducted brainstorming and subsequent emerging questions outside of the predetermined themes. Knowledge on three main motivators came up based on the data analysis, which are community, salary, and features of work. The work community motivates workers because of the coworkers and atmosphere being enjoyable. Additionally, analysis describes workers being satisfied with the salary. The satisfaction is partly because of the features of work in relation to salary, where workers enjoy the pay in relation to the work. However, the most significant motivator is the enjoyment derived from work, such as having access to good working facilities and tools, the ability to work on different products, and a general affinity for assembly work. In summary, employees are primarily motivated by their work.

The analysis provided insights into user opinions on three distinct features: one indicating competence, another for providing simple feedback to coworkers, and a third indicating activity performance. Some features were exemplified for interviewees, while others were suggested by the interviewees. The analysis also revealed insights into preferences regarding implementation platforms and points of feedback.

The first feature indicating competence was presented as a profile. The data analysis suggests that the effectiveness of such a feature is dependant on the implementation. The second feature for giving feedback was exemplified as a button on a coworker's profile where one could give a +1 for teamwork or helpfulness, received mixed opinions and is therefore not considered for the artifact. The third feature for indicating how well an activity was done was exemplified as a historical bar chart. The data for this feature should be kept private and used for personal improvement. Feedback could involve comparing completion to theory and self-performance. Gamified features should be proportionate to the product complexity, considering configurations that may result in longer or more complicated assembly activities. It is important to maintain a neutral tone when providing feedback. The preference for mobile implementation is noteworthy, as the system is currently only available on PC. The system does not reflect the users' preference for mobile. The preferred point for feedback in the manufacturing process was determined to be either after product completion or more frequently, such as after phases.

The insights into user motivations and their opinions on features inform design concretely, including the importance of implementation, platform preferences, and privacy concerns. Workers are mainly motivated by the work itself. Neutral-toned feedback should be provided between activities or phases.

5.3.3 The player persona

Based on the user and context analysis, a player persona representing the average manufacturing cell assembly worker is presented in Figure 13. It is a graphical, fictionalized version of the average assembler in a manufacturing cell.

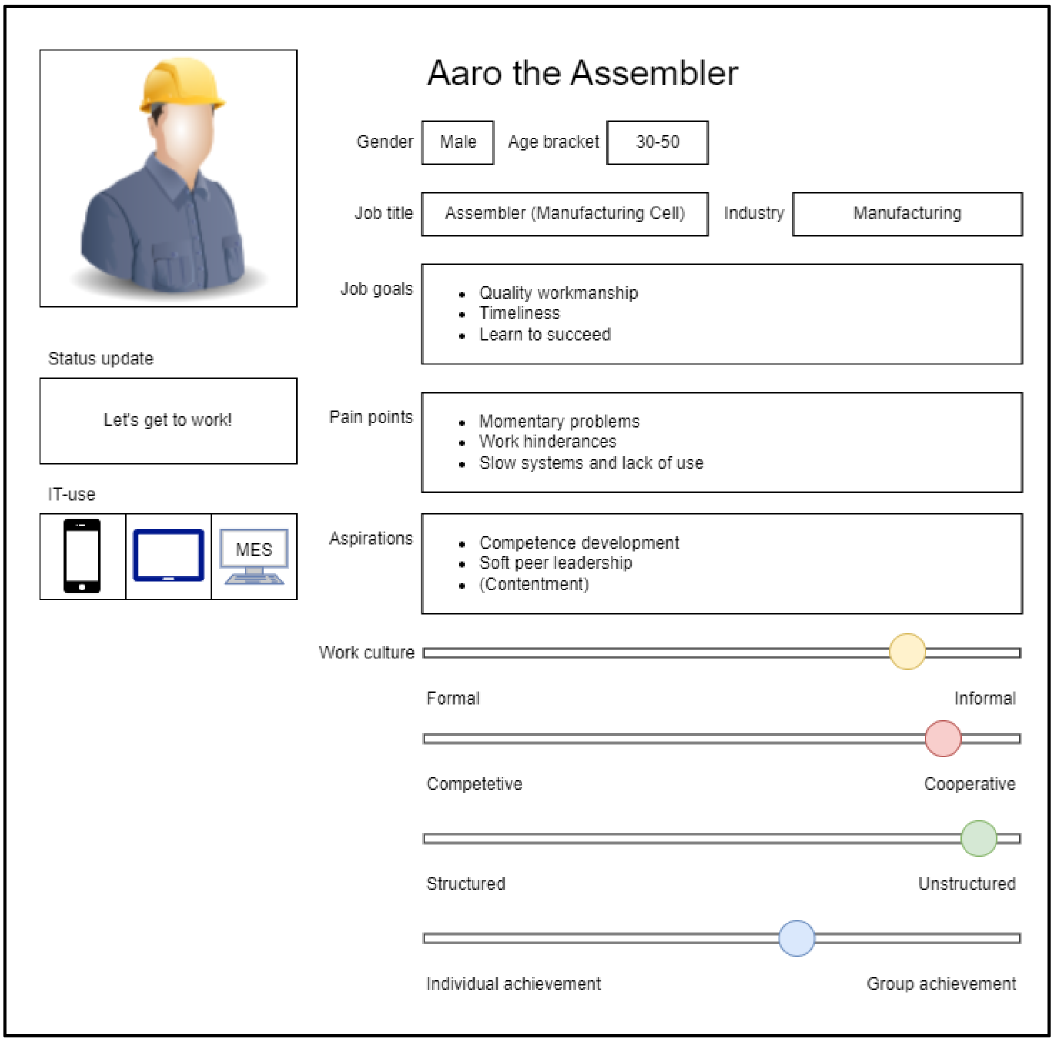

Figure 13. Resulting player persona.

The player persona (Figure 13), abbreviated to persona, is based on qualitative data gathered and analyzed in this research. It could represent more than the six interviewees because two interviewees had confidence to represent a larger team, while four could represent themselves. The persona’s (Figure 13) design is also based on observations, not just interviews. While exceptions to it can certainly be found in the work community of assemblers, the single persona is chosen to inform design. The persona is defined to represent users to minimize complexity. With the persona set, gamification can better be designed to fit the user that the persona describes.

The template by Kumar (2013, p. 46) as presented in Figure 5 is modified to fit the results of data analysis for this research. The relationship status is excluded as it was not planned as gatherable data. Friends and groups are also absent from Figure 13, as they require more data, and thus are not in the gathered data. The interviewed and observed workers are of different ages, thus age is depicted as a range of age brackets. The persona now includes information on the users’ IT usage habits, which can inform gamification implementation. The interests sections is removed as unnecessary because Kumar (2013, pp. 38–46) does not justify having them.

The job title of the persona is assembler, with the clarification of manufacturing cell, as data was mostly gathered from manufacturing cells, and workers in for example line work may differ. The persona’s industry is manufacturing, which is a general term, and could be specified. But this research keeps the case company and its specific industry in manufacturing classified. The persona’s gender and industry are based on observations. Its age, interests and IT-skills are mainly based on user analysis in chapter 5.3.2, with some knowledge from the context analysis in chapter 5.3.1. The persona’s job goals, pain points, and aspirations are the sub-themes formed in user analysis (Figures 6–8). The positioning of the dimensions of the persona’s work culture are based on the scales in user analysis (Figures 9–12). The status update of the persona (Figure 13) reflects the general attitude of the fictional generalized assembler inferred from the data analysis.

5.3.4 Gamification that fits the context and the users

This part of the chapter discusses the possibilities for gamification that fits the context and the users, as they are better understood now because of analysis. Six gamification design principles are defined in Tables 9–14 by combining knowledge of users, context, and literature. This part of the thesis presents the guidelines for how a gamified MES should be designed. The guidelines describe noteworthy aspects for gamifying a MES, which are compiled in the design principles. They are presented in an order from general considerations to more specific ones that can be distinguished as discrete affordances.

The guidelines and which design principle they result in are presented in Table 8. First, the general notions on design are presented, culminating in the design principle of good design (Table 9); second, the guidelines for privacy are summarized in the design principle of privacy and optionality (Table 10); third, the considerations for platform preference are summarized in the design principle of preference (Table 11); fourth, the suitability of points, badges, and leaderboards is considered and the guidelines that stem from it are encapsulated in the design principle of feedback on competence development (Table 12); fifth, the recognized need for more feedback on work and guidelines for providing it are explained and summarized in the principle of feedback on work (Table 13). Finally, guidelines for appropriate cooperation, are summarized in the design principle of mixed rewarding (Table 14).

Table 8. The described guidelines and the resulting design principles

Guidelines that describe	Resulting design principle
General notions on design	DP 1. Principle of good design.
Privacy	DP 2. Principle of privacy and optionality.
Preferred platform	DP 3. Principle of preference.
Points, badges, and leaderboards (PBL)	DP 4. Principle of feedback on competence development.
Feedback on work	DP 5. Principle of feedback on work.
Cooperation	DP 6. Principle of mixed rewarding.

General notions on design

The research question for this thesis is “how a gamified MES should be designed?” This answer cannot be completely answered by affordances alone. General notions on design and usability for instance should be considered. They cannot be straightforwardly put into elements, but instead into the mind of the designer. These notions are informed by literature, so this will summarize some of the main takeaways from chapters two and three. The Octalysis Framework by Chou (2019) is a good reference into how systems can motivate in the form of core drives. He takes the view of the human, and thus it can be used to think of gamification as its title aptly puts “beyond points, badges, and leaderboards”. To repeat a general guideline by Chou (2019), gamification for the workplace should aim to give meaning, relatedness, autonomy, as well as empowerment of creativity and feedback. Designing gamification needs usability like all systems. For instance, the system should be learnable, and gamified elements should use for example familiar terms and be relevant to the user (Magylaitė et al., 2022). Generally gamification should be designed bottom-up (Lessel et al., 2016) and kept simple, close, optional, interesting, and anonymous (Korn, 2023, p. 267). The metrics, such as quality measurement or user performance, that gamification is based on must be thought through and depend on the assembly process and specific industry. They should be relevant figures that employees care about. The first design principle of good design is introduced in Table 9, based on the considerations on the general notions on design.

Table 9. Principle of good design.

Design principle title	**DP 1. Principle of good design**
Aim, user, and implementer	For the designer (implementer) to bear in mind, to design high quality engaging gamification (aim) for employees (users).
Context	Good gamification design requires general notions on good design, as gamification is more than the application of game-like elements to non-game contexts.

Design principle title	DP 1. Principle of good design
Mechanism	Consider designing gamification holistically, as design guidelines and recommendations found in literature provide broad ideas on how to approach the design process.
Rationale	Because the design guidelines in literature such as Octalysis Framework (Chou, 2019), usability guidelines (Magylaitė et al., 2022) and recommendations for industrial production (Korn, 2023, p. 267) cannot be simply stated as elements one should implement, but as themes to keep in mind when designing.

Privacy

Gamification, and especially feedback which is discussed later, should be kept private as recommended by Korn (2023, p. 267) and as suggested in user analysis. User analysis pointed out opinions on features, such as the need for private, personal competition. In general, gamification features should be optional (Huotari & Hamari, 2017, p. 26), with the user in control (Magylaitė et al., 2022, p. 7). This research notes practical optionality as the ability to turn off and hide gamified elements from the UI. Based on these notions, the second design principle of privacy and optionality is introduced in Table 10.

Table 10. Principle of privacy and optionality.

Design principle title	DP 2. Principle of privacy and optionality
Aim and user	To allow employees (users) privacy and optionality in the gamification implementation (aim).
Context	Gamification can gather data seen by some as sensitive, and additional elements it brings as distracting
Mechanism	Keep gamification optional and its data such as feedback private from other systems and users
Rationale	Because optionality and privacy is recommended for gamification (Korn, 2023, p. 267), and privacy is suggested by user analysis.

Preferred platform

Context and user analysis pointed out dissatisfaction towards the platform where MES is currently being used. The persona (Figure 13) points out that workers are accustomed to mobile devices, such as phones and tablets for their IT-use, and pain with slow systems. The context analysis points out that there is a wish for a mobile application. Opinions on suggested features also stated that the use of features like a competence profile or feedback-giving depended on the execution, with emphasis on a mobile implementation. Analysis of the player persona (Figure 13), context, and opinions on features therefore points to a preference towards the convenience of mobile.

If the current state of a MES is inconvenient or slow, implementing gamification might not be the answer. This is part of what Morschheuser et al. (2018) point out in the sixth design principle in Table 1, companies should assess if gamification is the solution to problems. Slow systems or otherwise bad user experience might be a larger problem that needs addressing before implementing gamification. Gamified MES design should take into consideration the preferred platform of potential users. Of course, such applications are constrained by technology and available resources. In short, the user opinion in this research shows that some features might not be used or enjoyed when implemented on an inconvenient base system.

It is worth bearing in mind that literature generally states that gamification for manufacturing is needed in the future. For example Korn (2023, p. 252) states that newer generations entering the workforce have different expectations for the design of systems used at work. Chou (2019) adds to the characterization of these generations, describing them as being used to environments that support human motivation like meaning and relatedness.

From these considerations on user preferences, the third design principle of preference is defined in Table 11.

Table 11. Principle of preference.

Design principle title	DP 3. Principle of preference
Aim and user	To implement gamification on platforms preferred (aim) by employees (users).
Context	Gamification can lose efficiency when implemented on systems with larger issues such as slowness or bad UX.
Mechanism	Consider whether gamification is the primary solution, or whether it should be implemented on a user-preferred platform such as mobile instead of PC.
Rationale	Because users have different preferences for IT use or might avoid the current system for reasons that overwrite gamification's efficiency, wherefore gamification might not be the primary matter to attend to (Morschheuser et al., 2018, p. 10).

Points, badges, and leaderboards (PBL)

The suitability of the popular blueprint of gamification, PBL (Koivisto & Hamari, 2019) should be considered when gamifying a MES. Ulmer et al. (2020) recommend a scoring and skill system specifically for GfM. It can be seen as one interpretation of points and badges, thus supporting the approach of designing such elements for a MES. Badges, skills, and achievements are synonyms depending on the implementation, whereby the achievement framework defined by Hamari and Eranti (2011, p. 16) could be used. A Manufacturing Execution System has tasks that must be executed, from the employee's point of view, which can be grounds for the gathering of, for instance, experience points (XP). The gathering of points should be neutral, passive, and not based on time. From an employee's point of view manufacturing tasks involve different products or objects requiring different skills. Thus, there are badges for skills and points to be gathered for tasks. This could be in the form of a skill system. According to the player persona, assemblers aspire for competence development, which can be gamified via badges or a skill system. Thus, feedback on competence development can be visualized. Badges could be rewarded for a certain amount of a certain product's activities completed, or whenever competence could be identified as achieved for certain work. The skill system would entail a personal "expertise profile". The profile should show the skills or badges that the user has acquired, in addition to a wide variety of other information that users would like to see.

There are problems which could also be seen as possibilities when it comes to XP and a skill system. A problem with XP is its assignment. In the analyzed MES, users mark activities as started and completed sporadically, as in they might be completed by someone else, who did not do the work required by the activity. This could lead to XP gathered by someone who did not gain actual work experience. However, possibilities to change user behavior lie with the affordance of XP. If users understand that for them to gather XP, skill points, or badges for instance, they must mark their work accurately in MES. The motivational outcome of wanting to keep MES up to date on their accounts could lead to the behavioral outcome of increased and more accurate usage of MES. This could alleviate the persona's (Figure 13) third pain point for the part of lack of system use. The problems with a skill system are downstream of XP's problems, if the skill system is based on XP. Users would not have accurate skills in the system if they have not gathered accurate XP. The inaccuracy of these affordances could lead to its data being less useful. The problems and their possibilities are at this point speculation, therefore iteration (Table 1, no. 4) and monitoring (Table 1, no. 9) of them is needed, as suggested by Morschheuser et al. (2018).

Leaderboards are one of the three often implemented affordances. In a company with people working with similar tasks, their work could be comparative. Thus, there could be leaderboards for who or what team is leading, for example, in most manufacturing tasks of one type accomplished. However research on work contexts posits that competition might not be appropriate for manufacturing settings (Alavesa et al., 2019; Wallius et al., 2021). The persona (Figure 13) informs the emphasis on cooperativeness in the work culture. Context analysis noted the general atmosphere of camaraderie, which could be disturbed by pushing competitiveness through gamification. Thus, implementing competitive elements in general should be carefully considered, if not downright avoided altogether.

Based on the considerations on PBL, the fourth design principle of feedback on competence development is introduced in Table 12.

Table 12. Principle of feedback on competence development.

Design principle title	**DP 4. Principle of feedback on competence development**
Aim and user	To allow employees (users) to visualize their competence development (aim).
Context	Various experience and skills are being developed while working and carrying out activities.
Mechanism	Earnable XP from activities that contribute to the skills in the competence profile, for example via an achievement framework (Hamari & Eranti, 2011, p. 16), and careful consideration or avoidance of leaderboards.
Rationale	Because scoring and skill system is recommended for GfM (Ulmer et al., 2020), and because employees have aspirations for competence development (Figure 13).

Feedback on work

One of the objectives for this research is to come up with ways to give feedback to the user. Context and user analysis identified that the case company's MES provides no feedback to the user. Analysis pointed out that users prefer feedback given after a job is done, either after a phase or after an entire product. Gameful affordances such as feedback on quality or time could support the job goals of the persona (Figure 13). For that, suitable game elements for manufacturing suggested by Keepers, Nesbit, and Wuest (2022) include for instance displaying progress, notifications, performance as well as other feedback. User analysis informs that hurrying workers should be avoided to avoid mistakes, so elements based on time constraints are not fitting.

When considering displaying progress, in the context of manufacturing, there is a point where manufacturing for a certain object starts and ends. Thus, there is progress being made from zero to one hundred percent. This is the grounds for a progress-oriented affordance such as a progress bar. For example, a simple completion percentage at the top of a product's assembly information, as in "Completion 50%", as well as the status of completed activities per each phase, as in "5/10" and color accordingly, with green if all activities are marked complete, as in "10/10".

In a fast-moving manufacturing environment, products move fast, and activities started may be completed by someone else. Showing notifications or for instance a recap of things that have happened while the worker has been away, could be shown optionally or after logging in. Running notifications could show events such as milestones or finished products around the factory. Showing workers the bigger picture inside a big factory could feed into the Chou's (2019) core drive of meaning. The feature suggested by user analysis for indicating performance regarding activity, gave an example of a historical bar chart. User opinion on such a feature stated that it should be set in proportion to product complexity. An affordance that gives feedback on performance could be shown after all or only certain activities. The option should be given to users about what activity's performance they would like to get further feedback on. For example, if a worker would like to improve in a certain activity, they could enable "see feedback after completion". The fifth design principle of feedback on work is introduced in Table 13. It is based on the above considerations of feedback on work and exemplified affordances.

Table 13. Principle of feedback on work.

Design principle title	**DP 5. Principle of feedback on work**
Aim and user	To allow employees (users) to get visualized feedback from their own work and the surrounding work environment (aim).
Context	When executing activities and completing phases, work of some quality progresses in a certain timeframe.
Mechanism	Provide comprehensive and proportionate feedback on important metrics via progress indicators, notifications, performance display, without causing hurry.
Rationale	Because such affordances are recommended for GfM (Keepers, Nesbit, & Wuest, 2022), could provide meaning (Chou, 2019), and are suggested by user analysis.

Cooperation

The player persona (Figure 13) aspires for soft peer leadership and the work culture is cooperative. Data analysis also shows that “us” and “we” are spoken often. This is the basis for cooperative affordances for gamification in this manufacturing context. Three cooperative design approaches could be taken depending on who to reward: individualistic, collective or their hybrid (Riar et al., 2022, pp. 15–18). User analysis indicates that workers collaborate. They describe that the sense of community motivates them. Additionally, the products are made as a team and responsibility is shared among the members together. This points to collective affordances being appropriate, although individualism can be identified from analysis. The persona’s (Figure 13) work culture is torn between individual and group achievement. Their aspiration to competence development is individualistic because they want to improve as an individual worker. The individualistic tint therefore points toward hybrid or mixed reward design being appropriate for this context. Therefore, gamification that rewards both the collective and the individual should be designed. Examples of such are both team and individual goals, or separate competence profiles for teams and individuals. Mixed rewarding carries the risk of interest between self and the team conflicting (Riar et al., 2022), which means that iteration, monitoring, and evaluating implementations is required (Klevers et al., 2016; Kumar, 2013; Morschheuser et al., 2018). Based on these considerations, the sixth and last design principle of mixed rewarding is introduced in Table 14.

Table 14. Principle of mixed rewarding.

Design principle title	**DP 6. Principle of mixed rewarding**
Aim and user	To support the cooperative environment and individualism (aim) of the employees (users).
Context	In a cooperative environment such as manufacturing, teams work together to meet their goals and improve both as individuals and teams.
Mechanism	Gamification should reward both the collective and the individual.
Rationale	Depending on user analysis of for example work culture (Figure 12), users want to get feedback and rewards as both teams and individuals (Riar et al., 2022, pp. 15–18).

The guidelines and their summaries as the design principles (Tables 9–14, DP 1–DP 6) represent generalized knowledge applicable to design. They guide how a gamified MES should be designed.

5.4 Demonstration of the artifact

The artifact is demonstrated with eleven proof-of-concept design mock-ups as wireframes. The demonstrations are created based on the design principles and their underlying guidelines. How the design principles defined in 5.3 apply to each of the mock-ups is shown in Table 15. Wireframes are the first mock-ups to be implemented, as they show how elements are structured in the space of a user interface, and contain no visual design such as branding or color (Emond & Steins, 2011, p. 90). The mock-ups in this research have color for clarity. For example, to indicate navigation, as in to show that "Assembly" function is selected. The eleven mock-ups in this chapter (Figures 14–24) conform to design principles set in the previous chapter (5.3.4, Tables 9–14) as shown in Table 15.

Table 15. Design principles applied to mock-ups.

Design Principles	**Applied to mock-up figures**
DP 1. Principle of good design.	All (Figures 14–20).
DP 2. Principle of privacy and optionality.	All, esp. Figure 15.
DP 3. Principle of preference.	All (Figures 14–20).
DP 4. Principle of feedback on competence development.	Figures 14, 16, 21, 22, 23.
DP 5. Principle of feedback on work.	Figures 14, 16, 17, 18, 19, 20.
DP 6. Principle of mixed rewarding.	Figures 14, 16, 17, 18, 24.

The principle of good design (DP 1, Table 9), the principle of privacy and optionality (DP 2, Table 10), and the principle of preference (DP 3, Table 11) are in the background of all mock-ups, as they constitute general considerations for gamification, and as such cannot be discerned into any discrete element or affordance demonstrated in the mock-ups, with the exception of DP 2 in Figure 15. Which illustrates the principle of privacy and optionality (DP 2, Table 10), whereby gamification can be disabled with an option button. The mock-ups are designed to fit the user preferences defined in this research, meaning the mock-UI could be applied on mobile tablets. The users preferred mobile phones as well, but the mock-ups are not for such a small screen. They are designed for larger screens, for the guidelines to stay actionable and for them to not need huge changes, seeing as the current MES is used on a normal 24-inch computer screen.

The principle of feedback on competence development (DP 4, Table 12) is applied in Figures 14, 16, 21, 22, and 23. The mock-ups illustrate how a system involving experience points (XP scoring), and achievements (skills) resulting from gained XP would look like. It enables the aim of visualizing competence development for employees. The principle of feedback on work (DP 5, Table 13) is applied in Figures 14, 16, 17, 18, 19, 20. These mock-ups illustrate for instance visualized progress and feedback. The principle of mixed cooperation (DP 6, Table 14) is applied in Figures 14, 16, 17, 18, and 24, where there are elements that reward both individuals and collective. Figures 21, 22, and 23 support the principle of hybrid cooperation (DP 6, Table 14) with profiles for the individual employee.

The first mock-up to demonstrate a gamified MES is shown in Figure 14, where DPs 4 and 6 together, as well as 5 are highlighted. MES is in this case represented as a cloud-based browser application. The main functionalities are laid out on the top right. Mock-ups concerning the assembly and profile screens will be shown in this chapter. The phase view is the main view when completing tasks in this mock-up MES.

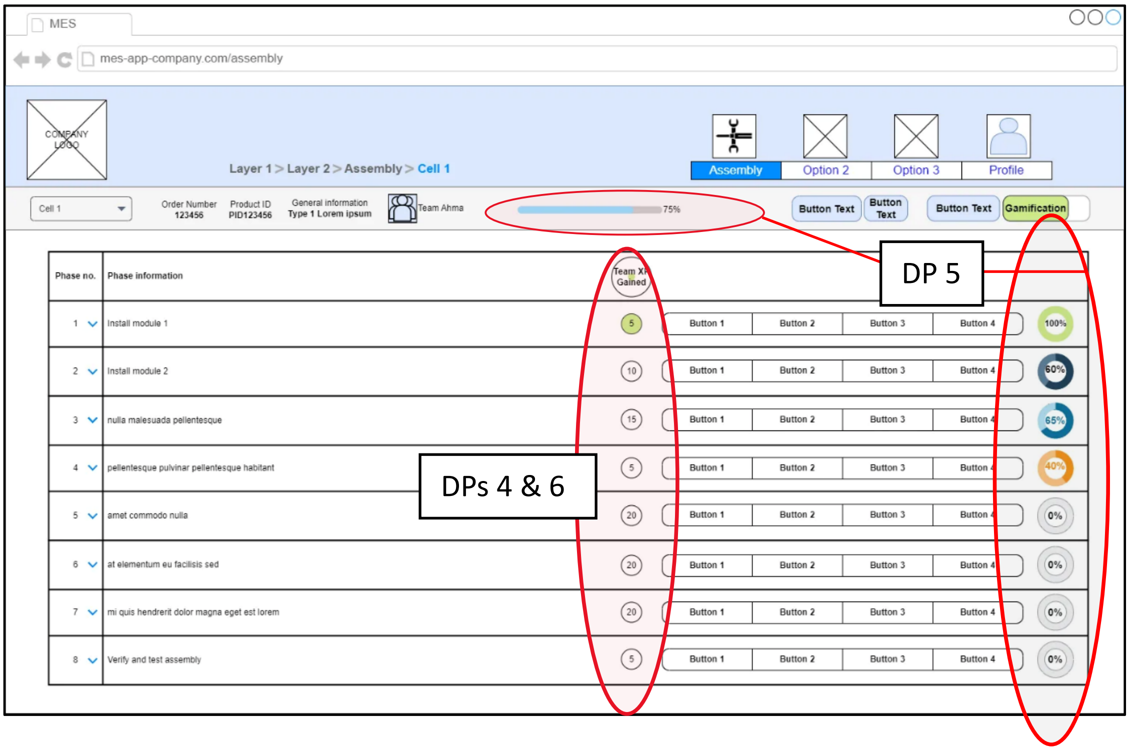

Figure 14. Mock-up of main assembly view.

The area below company logo and above the main phase view, the info-area, shows relevant information regarding what “Cell 1” is working on, and what team is in it. The team feature is gamification, as it can feed into the social element. Features around the team are introduced in this chapter. The info-area has the first important gamification feature, a toggle button for gamification. The easy-to-access option instantly removes gamified elements from UI, according to recommendations for user control by Korn (2023). A mock-up showing gamification toggled off is shown in Figure 15, illustrating DP 2. The second simple gamification element, an overall progress bar, is in the middle of the info-area. It shows a fast insight into the progress of a single cell, based on the progress in each phase.

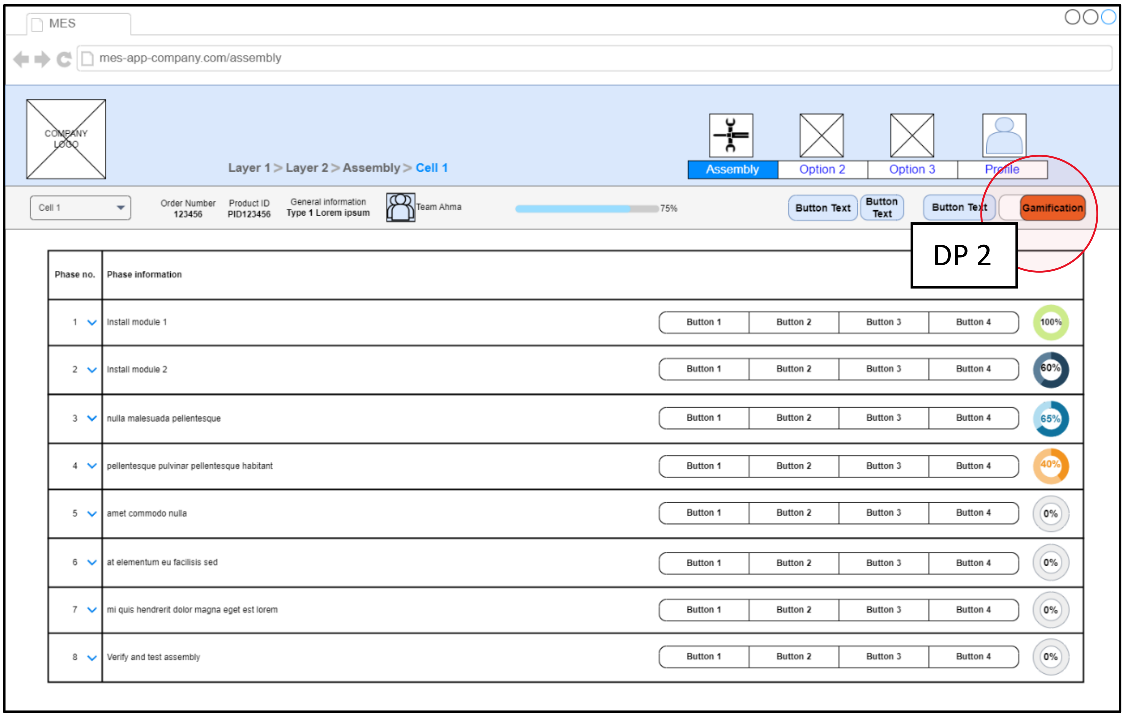

Figure 15. Mock-up of main assembly view with gamification disabled.

The mock-up of the main view (Figure 14) has a list of phases, and an example of a scoring system, modelled as XP (experience points) in this demonstration. Phases could grant Team XP, making it a cooperative affordance. Workers get positive feedback from it, showing that what they are working on is rewarding the team. The idea behind the circles turning green is visualization of feedback. The unobstructive visualization shows feedback without getting in the way. The further the product is completed, the greener the overall team XP circle turns. After each phase is completed, its XP circle turns green, along with the phase's progress indicator. The XP earned from a phase could depend on the complexity. Some phases could grant more team XP, for instance those that take longer or are more difficult.

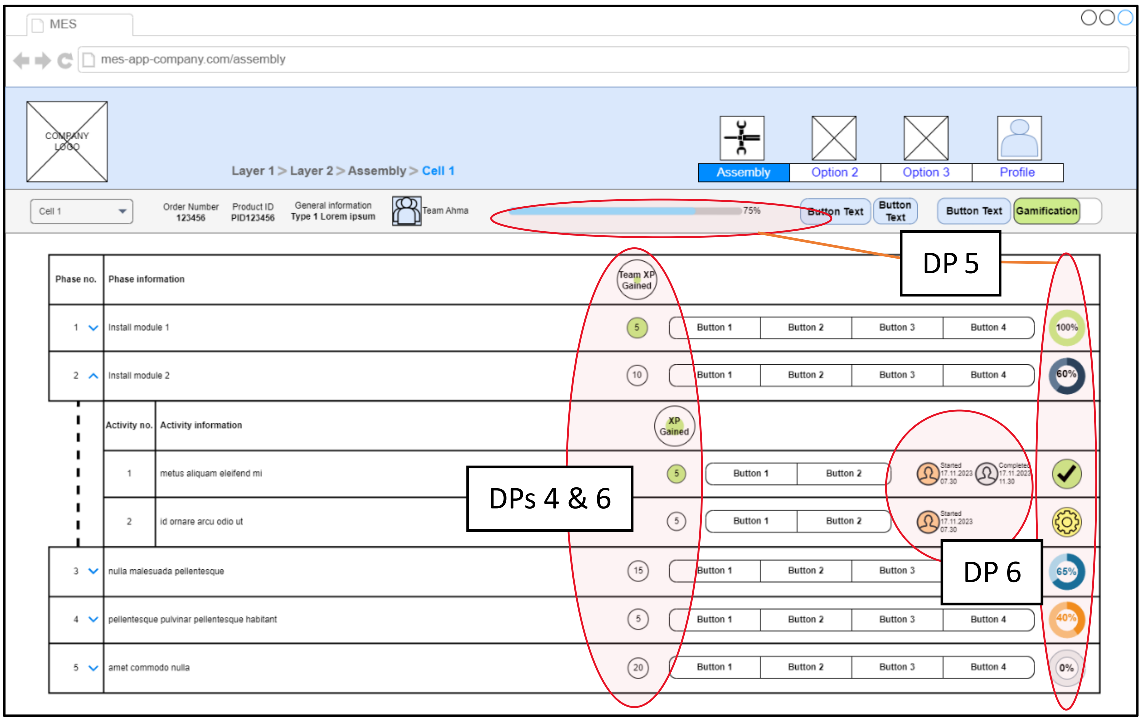

Figure 16. Mock-up of main assembly view, phase opened showing activities.

The XP feature could be turned into a hybrid cooperation feature, as in rewarding to both the individual and the collective, by instantiating individual XP gain affordance as shown in Figure 16. The applied DPs 4, 5, and 6 are highlighted in red. If phases rewarded team XP, each activity within the phase could reward individual XP. The observed MES in this research features two points of contact with an activity: the starting and completion of an activity. It is difficult to ascertain who does the actual work, and thus earning actual work experience. This affordance could indeed affect behavior, having workers complete activities in MES accurately, and not after-the-fact. XP could all be granted to the same worker if they both started and completed an activity. If the activity was started by another worker and competed by another, the XP could be split between the two, as in the case of phase two's first activity in Figure 16. For example, the user avatars could be shown in the UI for starting and completion of the activity. As illustrated in Figure 16, on the right of the opened activity no. 1, the worker who starts the activity has their avatar along with the activity start date and time shown on the UI first, and the worker who completes the activity has their avatar as well as the end date and time shown on the UI after. The user avatars are a simple feature which should be implemented to support further gamification demonstrated in this chapter.

Feedback affordances like info-screens were suggested by users themselves. Therefore, a MES should show feedback that the employee deems useful. User analysis determined that feedback would be appropriate after phase completion, and that it should consider product complexity. A mock-up of such feedback is shown in Figure 17, as a popup screen after a user has marked a phase as completed. DPs 2 & 5 are highlighted in red. Such a screen could show for example a chart showing historical data regarding important metrics. In this mock-up example (Figure 17), quality and time is compared on a scale of previous phase completions. More detailed representation of data is up to further planning and implementation. The people involved in the phase could also be indicated as a social element. The third suggestion could be a pie-chart showing how much time was spent on each activity.

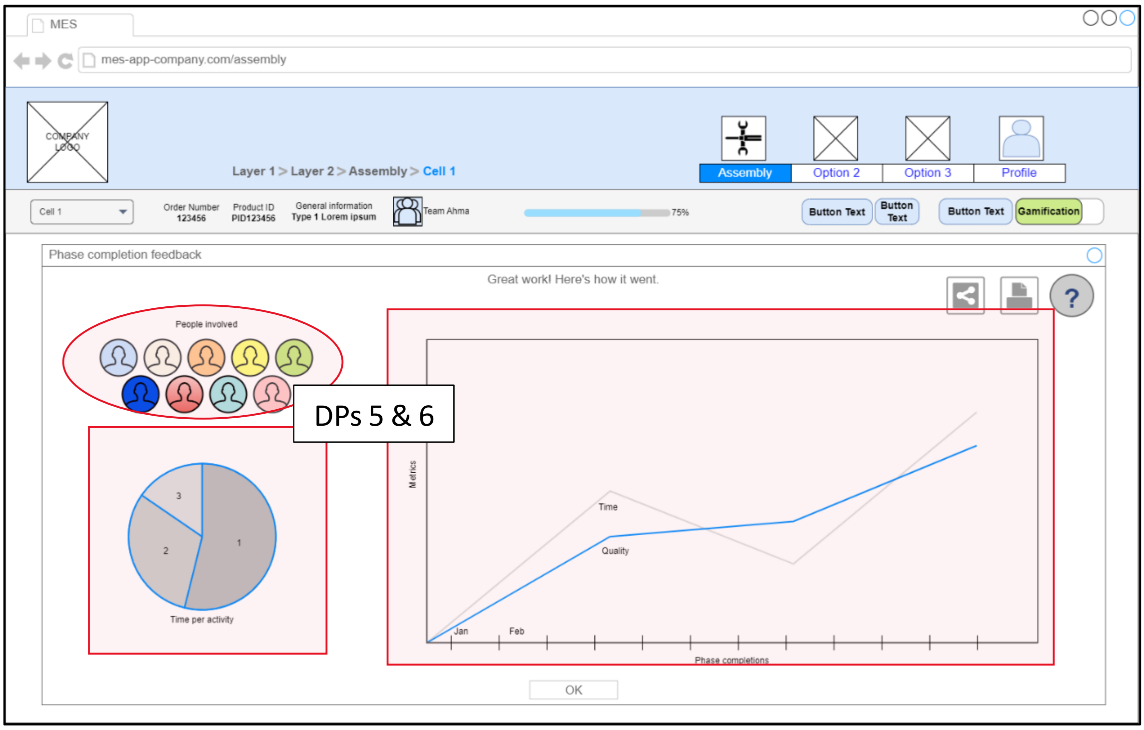

Figure 17. Mock-up of a feedback popup screen on phase completion.

As identified in data analysis, specialized teams that move between cells do not complete entire phases. Instead, they perform certain activities throughout the factory floor. These workers could gain from activity-specific feedback, which is presented in Figure 18. Applied DPs of 5 and 6 are highlighted in red. Here as in with the other feedback screen, information that workers are interested in could be shown, via charts for example. If the activity resulted in a badge or achievement, such information should be shown on the screen.

Figure 18. Mock-up of a feedback popup screen on activity completion.

The feedback environment of a MES could be improved by keeping the workers up to date on what is happening around the factory. Workers do shifts and are not always on site at the same time. Thus, notifications should be implemented into a MES, such as a recap notification, that summarizes important information while the user was, after logging in (Figure 19) or a heads-up notification, that notifies about current events (Figure 20). These mock-ups illustrate DP 5.

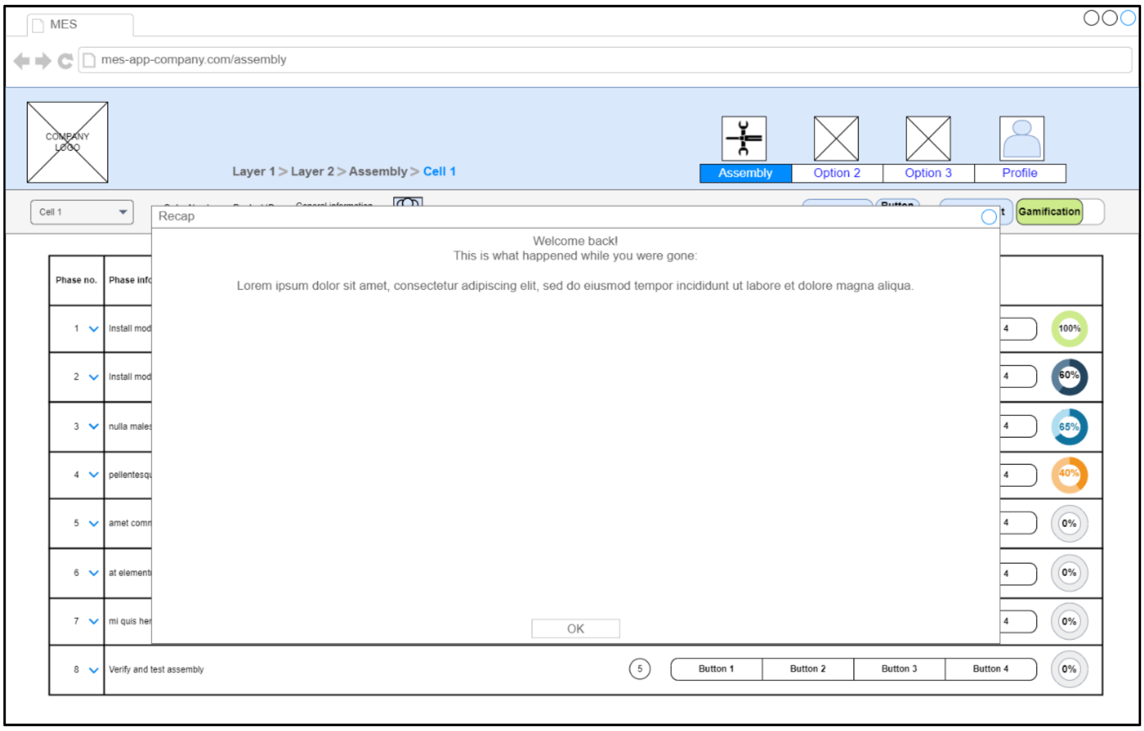

Figure 19. Mock-up of a recap notification.

The recap notification shown in Figure 19 should show information on what has happened in the factory while the worker was for example on an off-site assignment, on leave, or on vacation. The floating heads-up notification in Figure 20 could display current information on events around the factory floor. It is useful in a big factory as workers must focus on their own work, but knowing what happens around them adds to the feedback environment. The mock-up example (Figure 20) shows a notification about a team completing a product and showing its purpose and destination. The exact information to be shown depends on the context.

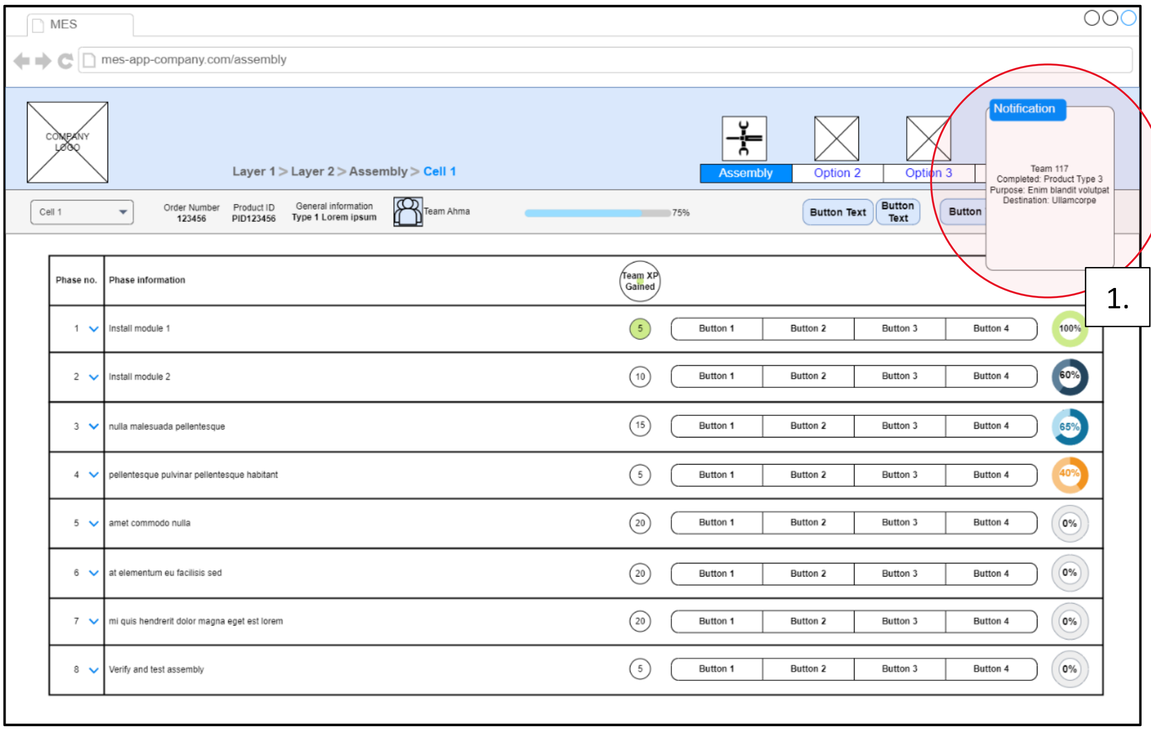

Figure 20. Mock-up of a heads-up notification in a floating window.

To support the XP scoring and skill system that would need to be implemented in the background, profiles should be implemented for workers. They should be private and show the expertise of the worker. The skills the worker acquires could be shown as badges or achievements as shown in Figure 21. It is based on DP 4 to support feedback on competence development, and supports DP 6, because it gives the individualistic rewarding tint to the overall cooperative aim of the operations. The mock-up also shows which team the profile is in. A separate team profile is discussed later in this chapter. There are several possibilities for information that can be shown in a profile. The exact information depends on the context. It should in any case show work-specific information regarding the individual. The sharing of information should be optional.

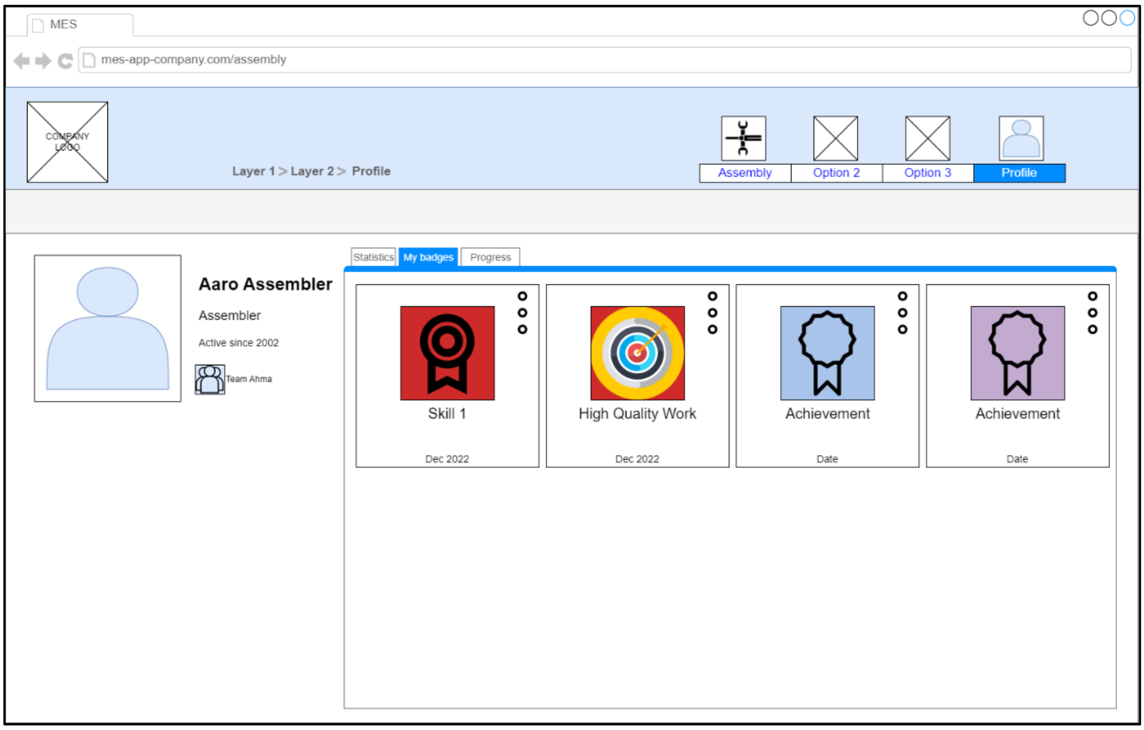

Figure 21. Mock-up of a profile.

The profile should progress towards badges or other achievements and skills, like for example in the mock-up of a profile's progress as shown in Figure 22. In it, badges are in progress, quantifiable by some metric such as the forementioned XP. The progress screen for an individual's profile would support goal orientation and the aspiration for competence development identified in the player persona (Figure 13).

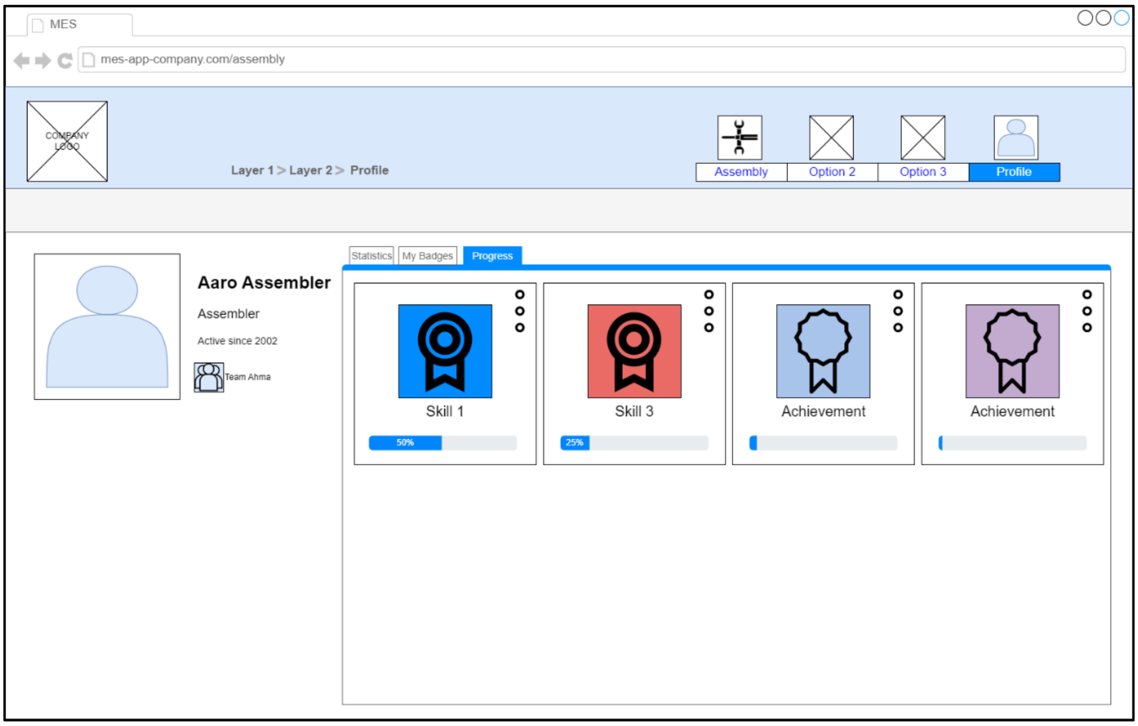

Figure 22. Mock-up of a profile's progress.

Context and user analysis pointed out that statistics are appreciated. Therefore, the profile could feature a statistics screen, such as in Figure 23. The information shown in statistics and generally in the profile could be as in depth as possible. For example, it could include statistics on all the different products and the amounts that the worker has assembled. It could list average assembly time overall and for certain products, phases, and activities. Users might enjoy seeing the number of defects they have reported. Another metric could be a quality rating, which implies how many defects have been reported in products that they have been working on, compared to the number of products they have assembled. Overall, the profile should show any statistics that users deem interesting. The profile mock-ups in Figures 21–24 illustrate DP 4 by visualizing competence development, and support DP 6 by adding the individualistic achievement dimension to the overall aim of mixed rewarding of both the individual and the collective.

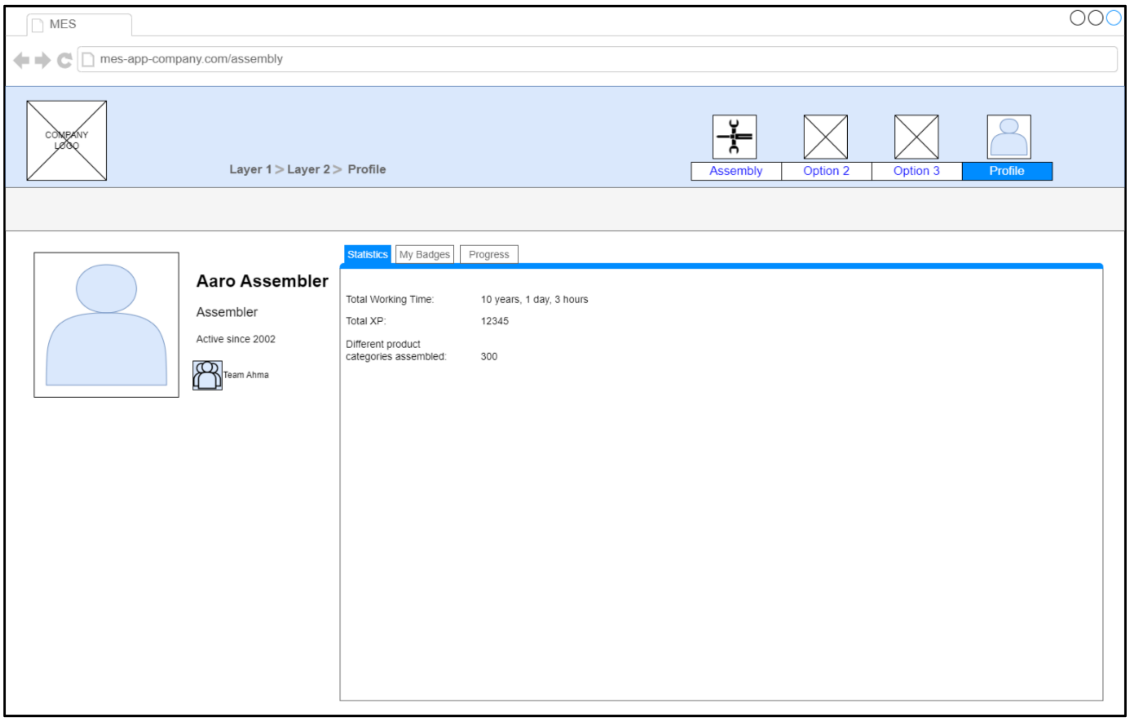

Figure 23. Mock-up of profile statistics.

A separate team profile could be implemented to support the hybrid gamification design. The mock-up in Figure 24 shows a team profile. It has the team picture, teammates' avatars, and information about the team. It illustrates DP 6, highlighted in red. Statistics that compare the individual to the team combine both DPs 4 and 6, also highlighted in red. The individual worker might enjoy seeing the most achieved badge or most frequent skill possessed by the team. The worker could reflect his statistics to the average of the team in some way, like completed activities or number of badges. This affordance could be construed as competitive, depending on the implementation. Like with the individual profile, teams could achieve team-specific badges. For example, a quality award for the least number of defects detected within the team's products in a year. The team-level badges, like all awards, should be planned carefully.

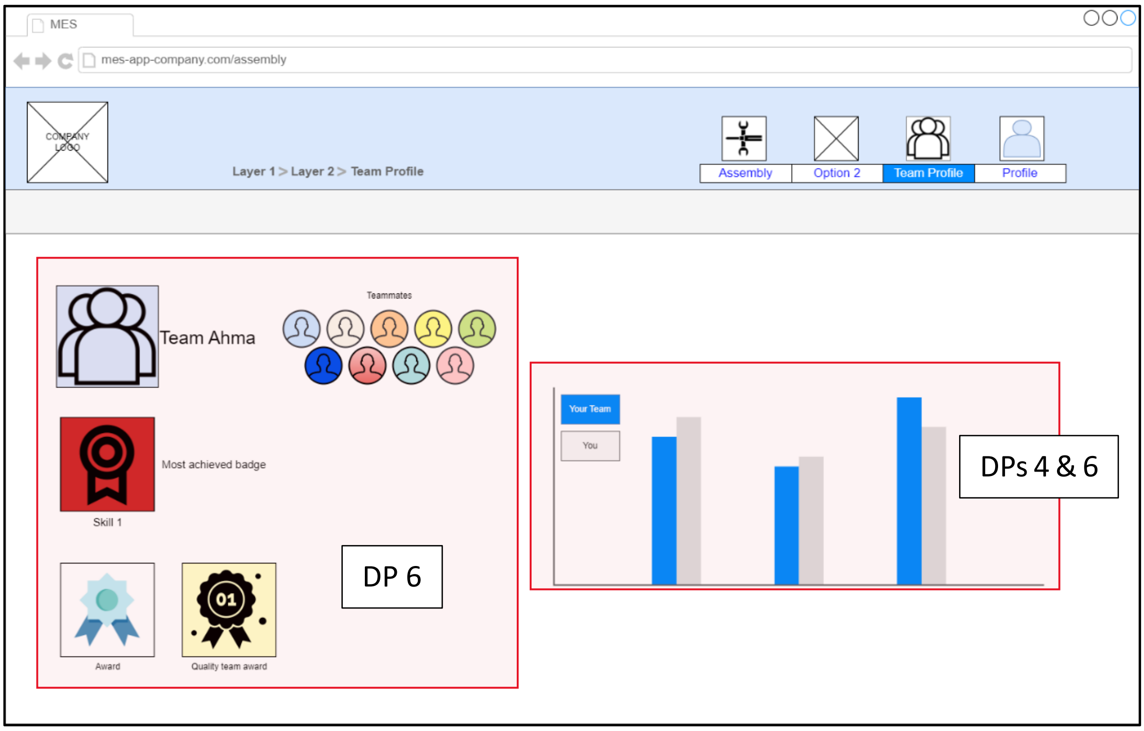

Figure 24. Mock-up of a team profile.

The mock-ups in this chapter demonstrate how the proposed design principles can produce a functional solution. In other words, the design principles inform how a gamified MES should be designed, and the demonstrations show how they can be used to bring gamified elements into a MES. The principles have been demonstrated as multiple mock-ups, which should give designers, who are concerned with gamifying a MES, intuition on where to start and how gamification could look like. The innovation involved in this research is not bound to what is demonstrated, and more possibilities lie in this inventive venture.

Feedback regarding the mock-ups was received from the case company. The feedback was received as a summary email reply to a work-in-progress version of this thesis. The feedback discussed terms, data privacy, as well as the data and cosmetic features to be shown in illustrated mock-up elements. It affected one change to the design principle of privacy and optionality. The feedback was from management and assemblers together, representing concerted feedback from the case company (personal communication, November 29, 2023).

The mock-ups show “Cell 1” being worked on in Figures 14–20, top left under company logo. A more generic term would have been “Assembly Station” because all products are not assembled in cells. However, analysis in this research focused on the assembly cells, therefore they are illustrated in the mock-ups.

Concern was raised regarding Figure 17’s and Figure 18’s “people involved” -feature’s data privacy restrictions. Showing other involved users, like other features showing people’s information, could be troublesome from a data protection point of view, which affected one change to a design principle. The feedback pointed out the need for GDPR considerations. The principle of privacy and optionality (Table 10) should therefore be adjusted to include the rationale of privacy legislation in GDPR (Regulation 2016/679, 2016). Considering the data privacy implications of mock-up features is however out of the scope of this research. The “people involved” in assembly could be a team member or other person working close by, therefore they would be known to the user beforehand.

Requests for more detail was presented in the feedback regarding the chart in Figure 17 . It shows exemplary time and quality curves. There were specific requests for detailed information to be shown on the graphs, such as statistics on disruptions such as material deficiency, and total time to resolve them. This demonstration introduces mock-up wireframes, with features involving color and examples for clarity. Therefore, detailed representations of data are grounds for further research and planning of certain gamification elements.

The feedback expressed confusion regarding Figure 18, which is a mock-up of a feedback screen on activity completion is introduced. It is like the prior mock-up of Figure 17, which is a feedback screen as well, but on phase completion. The case company feedback questioned what the screen on activity completion indicates and to whom. The reason for the depiction is that according to the data analysis, some users do not complete phases at all, but activities throughout the assembly stations. Also, the comparability of activities even with the same name is difficult according to the case company. Products have different configurations, and production is not serialized in this manufacturing context. This means that all features are not feasible, and some only fit into more serialized or standardized production, such as simple comparing of activity completion time as illustrated in Figure 17. The wireframe mock-up shows how elements are structured in the space of a user interface (Emond & Steins, 2011, p. 90), and the detailed representations of such elements as the graphs in Figure 17 and Figure 18 are topic for future work.

The case company had ideas for more detailed data that could be represented in Figures 21, 22, and 24. The achievements in Figure 21 could also be based on the amount of data the user has reported, for example certain quality defect reports. The profile statistics in Figure 23 could show comparative data, for example if an employee is in the Top 10 in a certain domain. It could also show amounts of certain product configurations assembled and the XP gathered from them. The team profile in Figure 24 was suggested to include more comparative data. For instance, the team could be compared to all teams, in addition to the user viewing the team profile. Other information suggested were indicators of performance. For instance, percentage of products assembled in target time, or how many addressed quality issues. This data was suggested to be compared to other teams.

Future research iterations could incorporate changes to the demonstrations based on the feedback. To manage inaccuracies and feature requests, it may be helpful to include company goals and recommendations for desired features and data. It is important to note that this research solely focuses on gamification from the employee's perspective and does not include further specifications from management. Nonetheless, an understanding of business needs and goals is required when designing gamification further (Klevers et al., 2016; Kumar, 2013; Morschheuser et al., 2018).

6 Discussion

This research was initiated as objective-centered because of the need to adapt systems for human-centricity coming from the Industry 5.0 transformation. The case company and its cooperating international manufacturing company are involved in a joint Industry 5.0 initiative which gives impetus to this research. They had determined the need to improve the feedback environment in their IT systems, and gamification was identified as the solution worth pursuing. MES was chosen as the IS to focus on, because it is the most used IS for the case company’s employees. Thus, the objective for research was to develop guidelines for gamifying MES, which constitutes the DSR artifact. Gamification of systems requires thorough analysis of context and users. Therefore, the design and development of the artifact involved context and user analysis as important steps before developing guidelines. The combination of understanding literature, context, and users resulted in appropriate gamification. The feasible guidelines were condensed into design principles, which were demonstrated in mock-ups.

6.1 Key results and contributions

The DSR process for this research started with an objective-centered approach, to develop a method for gamifying a MES, which is the DSR artifact to be established. From there the problem was identified as the need for more feedback from IT systems and improvement of UI/UX. Literature reinforced the need for gamification at work and in manufacturing. The design and development of the artifact resulted in guidelines and design principles that were demonstrated. Therefore, the main results of research in chapters 5.3 to 5.4 are:

- The design principles (Tables 9–14) and guidelines on how a gamified MES should be designed, based on the player persona (Figure 13) derived from user analysis, along with context analysis summarized in Table 6, as well as
- demonstration of design principles as mock-ups (Figures 14–24).

The method's guidelines were summarized into six design principles (Tables 9–14), which were demonstrated as eleven mock-ups (Figures 14–24). A gamified MES should be designed according to the design principles. The mock-ups illustrated the guidelines and design principles in multiple ways: main assembly view mock-ups with or without gamification elements, feedback popup screens, notifications, and profile screens. The mock-ups were assessed by the case company, which included feedback on elements' data-specificity and data privacy. The design principle of privacy and optionality (Table 10) was the only design principle that should be revised because of the feedback to include the rationale of data privacy legislation, for example to mention GDPR (Regulation 2016/679, 2016).

The research question of "how should a gamified MES be designed?" is therefore answered via guidelines, design principles and their demonstration. A gamified MES should be designed to fit the users and context, meaning that analysis of them is of utmost importance. In this thesis, a gamified MES that fits the users and the context should be designed to consider guidelines for good design (Table 9), allow for privacy and optionality (Table 10), consider user preference (Table 11), give feedback on competence development (Table 12) and on work (Table 13), as well as provide mixed rewarding (Table 14). Moreover, illustrative examples of gamified elements in a MES are shown in mock-ups that concretize the design principles. For example, optionality is illustrated as a button that immediately switches off gamification in Figure 15. The profile mock-ups in Figures 21–24, among others, illustrate how feedback regarding competence development should be visualized.

The player persona (Figure 13) combined analysis of the general user characteristics, sub-themes for the predetermined themes of goals (quality workmanship, timeliness, learning to succeed), aspirations (competence development, soft peer leadership, contentment), and pain points (momentary problems, work hinderances, slow systems and lack of their use), as well as work culture into a fictional representation of the average worker for whom gamification is to be designed. The player persona was used to inform the design of the artifact. It added to observations in context analysis (Table 6), meaning the design was based on a dual-pronged approach to analysis.

The results of this research provide practical contributions. The guidelines and design principles developed here address practical issues related to the design of a gamified MES. For instance, other companies can use the design methodology applied in this thesis to gain a better understanding of their application environment's context and users, and to build on the analysis presented in this research. For example, the user analysis methods can be used to create one or more player personas based on the predetermined themes in the modified player persona presented in Figure 13. These personas can then be used to generate iterations on the guidelines and design principles. The design principles can also be applied directly by the case company and other organizations whose context and users align with this research to contribute to the design of gamification for their MES. However, the results do not provide comprehensive implementation instructions. Instead, they offer practical guidelines and principles to guide further implementation.

The conducted research contributes to the field of GfM by providing empirical evidence and identifying gamification elements for the use case of a MES. This provides a basis for further defining of a framework that considers users and context. The research gap of empirical research and depiction of what elements to use in different use cases was identified by Keepers, Nesbit, Romero, et al. (2022, pp. 314–315). This thesis empirically researched the designing of a gamified MES for assembly and produced guidelines that included consideration on which elements to use. Keepers, Nesbit, and Wuest (2022, p. 460) called for development of a framework based on characteristics of the system and its operators. While this thesis’s research objective was not to create such a framework, the research methodology presents design based on such considerations of the system (MES), and its operators (assemblers). For example the methodology for defining a player persona, introduced by Kumar (2013, p. 46), was expanded upon. The information about the work culture was developed into scales (Figures 9–12) to define which way the culture tends towards, which built on the methodology by Kumar (2013, p. 46). This provides a basis for further defining the employed methodology into a discrete framework.

Furthermore, this thesis adapted gamification design methodology by Morschheuser et al. (2018). Their recommended user and context analysis was conducted in detail by qualitative methods of observation and interviews and their analysis. Therefore, this research introduces new novel methodology for detailed context and user analysis. With the conducted user analysis, this research delves further into employee perspectives (of assemblers in manufacturing), which was suggested by Wallius et al. (2021, p. 132). This thesis therefore adds to knowledge regarding gamification at work as well. Schuldt and Friedemann (2017, p. 1629) request development of gamification prototypes. The design principles (Tables 9–14) and its demonstrations (Figures 14–24) represent foundations, with which iterations involving a technical working prototype of a gamified MES could be developed. The mock-ups are closer to context and user characteristics than general descriptions of affordances, thus they can be used as basis or inspiration for further development of gamification in the application domain.

The research represents an improvement in the DSR Knowledge Contribution Framework (Gregor & Hevner, 2013, p. 345). The artifact utilizes methodology from various research studies, including user analysis method from Kumar (2013), context analysis from Spradley (1980), overall design method from Morschheuser et al. (2018), cooperation gamification from Riar et al. (2022), affordance guidance from Koivisto and Hamari (2019) and Ulmer et al. (2020). Other general notions on design (Chou, 2019; Korn, 2023; Lessel et al., 2016) and usability (Magylaitė et al., 2022) were also utilized. The research improves the designing of MESs, which are normally mundane and known applications. However, how they should be gamified is new knowledge. The design principles represent knowledge that is adapted to the manufacturing environment and user characteristics. The methodology to achieve the design principles is also new knowledge, which describes how the designing of gamified MESs could be conducted at the very starting point. The artifact improves MES design via specific-to-application-environment design principles demonstrated as design mock-ups, that directly inform design. The artifact's demonstration constitutes innovative illustrations as mock-ups, which are based on the design principles.

6.2 Alignment with DSR guidelines

The objectives of this research were aligned with the DSR guidelines for information systems research defined by Hevner et al. (2004, pp. 82–90). The first guideline of "Design as an Artifact" was followed by producing a viable artifact. The aim was to develop guidelines for gamifying a MES using state-of-the-art knowledge. The viability of the artifact was demonstrated as mock-ups, which were reviewed by the case company. The review included mostly data-specific requests and further details on specific elements, and no condemnation of viability. The method, as conceptual but actionable guidelines, was produced and summed up as design principles.

The second guideline of "Problem Relevance" is pursued inherently as this research is commissioned by two cooperating manufacturing businesses. The artifact is demonstrated in a relevant environment to the MES in the case company. The problem is identified according to the case company's knowledge of the problem, which is that employees find information such as feedback and production progress important to get from IT systems, moreover the case company does not know where to start with providing visual feedback to the employees (personal communication, October 12, 2023). Prior literature is not actionable enough, because the reviewed practices are on a general level. For example, there are design guidelines specific to the manufacturing application environment in general (Korn, 2023) and methods for designing gamification in general (Morschheuser et al., 2018), but these are insufficient to further inform gamification for MES and its specific context and users for this research. Gamification was seen as a worthwhile solution to pursue, with its importance reinforced in literature, for instance by realizing that future generations expect feedback (Korn, 2023, p. 252) among other meaningful aspects (Chou, 2019, pp. 58–59).

The third guideline of evaluating the artifact’s usefulness was carried out by gathering feedback on the demonstrations, without further methodological evaluation. Feedback was provided by the case company as a summarized email reply. The feedback was about further details and corrections. For example, the case company wanted some wording on the mock-ups changed from Cell to Assembly Station, which is a more generic term. Also, there was misunderstanding of feedback mock-ups. Additionally, they had ideas for where more detailed data could be represented in some mock-ups (personal communication, November 29, 2023). Future work should include evaluating the artifact's feasibility and usefulness in adding value when it is widely used.

The fourth guideline of research contributions (Hevner et al., 2004, p. 87) was followed as conducted research contributes to the field of gamification for manufacturing. The conducted research provides guidelines and design principles for the specific target system of MES. As discussed in the key results and contributions prior (Chapter 6.1), the research bridges gaps regarding empirical research and depiction of gamification elements in a use case (Keepers, Nesbit, Romero, et al., 2022, pp. 314–315), and basis for a design framework based on considerations of the system and its users (Keepers, Nesbit, & Wuest, 2022, p. 460).

Research rigor, as the fifth guideline by Hevner et al. (2004, pp. 87–88), is applied throughout the conducted research. This thesis begins with the narrative literature review, followed by the description of research methodology, which is executed in the research process. DSRM is the main methodology, supported by qualitative research and design practices from literature. The research is conducted and presented according to the DSRM process model defined by Peffers et al. (2007, pp. 52–56). Qualitative research methods are used to gain knowledge of users and context. Data is gathered as a combination of shop floor observation and semi-structured interviews, which gives a diverse insight into the application domain. The interviews were planned according to the dramaturgical model by Myers and Newman (2007) to ensure important considerations are taken into account. Qualitative data analysis formed knowledge on context and users which was used to develop context descriptions and the player persona.

The rigor involved in the results of data analysis in addition to practices identified in the literature review were used to inform design and development of the artifact. The artifact's guidelines were based on analysis of context, users, and literature. They were then summed up into design principles according to the schema defined by Gregor et al. (2020, p. 1633). Innovative mock-ups were designed to demonstrate the artifact. The research did not tie itself to any single methodology, because there was no single practice that enabled the reaching of the objectives of the solution, or allowed the research to stay relevant, or empowered the complete answering of the research question. Therefore, careful application of methodology and practices were used in the manner of a mixed method, to ensure objectives were reached while staying relevant to the business and answering the research question.

The conducted research represents the sixth guideline of "Design as a Search Process" (Hevner et al., 2004, pp. 88–90) in that the solutions came from the search for and analysis of literature, users, and context. The case company had ideas of what they wanted from gamification, but the search process and resulting knowledge was needed to truly understand the application environment and to aptly design for it. Without the search for diverse knowledge, the resulting artifact would have been insufficient as a solution.

The communication of this research, in accordance with the seventh and last guideline (Hevner et al., 2004, p. 90), was planned to be understandable by both technical and managerial audiences. No separate reports are made to communicate the research other than this thesis. The resulting artifact gives guidance to the designers and implementers of gamification, which is therefore useful knowledge to the technical audience. The visual mock-ups in the demonstration give the managerial audience a definite and immediate idea of what appropriate gamification in MES could look like. By using the wireframe mock-ups as a starting point, designers and managers can jump straight into planning for what further details and data the illustrated features could include. Communication during the research and its phases was kept up on both the case company's and researcher's side. Time restraints set on the research resulted in only users being interviewed. The initial plan was to interview upper-level management and developers as well, but that had to be ruled out due to time pressure of the surrounding project, which this thesis is part of.

6.3 Limitations of research and recommendations for future research

The research process executed in this thesis constitutes a single iteration of a wider and larger design process. Future iterations should consider company needs or build on the mock-ups with detailed data to iterate on the design principles based on feedback. The research is human-centric and considers the employee's point of view accordingly. Nevertheless, to be truly efficient, gamification design should include company objectives, which were not considered further in the design and development of the artifact. Suitability of gamification to company needs is recommended in multiple gamification methods and models (Klevers et al., 2016; Kumar, 2013; Morschheuser et al., 2018), by for example the use of key metrics that should be determined well in advance.

The user analysis could be done on a larger and more accurate scale, with a larger pool of interviewees and a wider range of predetermined themes. This would allow for the creation of multiple player personas, and the including of Bartle's player type (Bartle, 1996; Kumar, 2013). Although the employee's work culture appeared to vary slightly across teams, the research resulted in a single player persona. However, a wider sample could reveal additional player personas.

To improve accuracy, a longer and more informed context analysis could have been conducted. Due to time constraints, the observations were limited to four hours, which left room for errors and inaccuracies. The focus on cells within one factory's facilities provided a limited view of the complex manufacturing business. Given the many variables in the big picture, the research scope had to be significantly limited. The research's limited scope was both a strength and a weakness. On the one hand, it allowed for a focused and detailed analysis. On the other hand, it overlooked important information about the wider context, such as other facilities and assembly stations that may have differed from the manufacturing cell that was the focus of the study. Additionally, further insight into the technical context is necessary for actual implementation, which was not addressed in this research.

In general, a more comprehensive empirical approach could be taken to gain an even deeper understanding of the context and the users. The research’s empiricism in this research suffered from lack of data stemming from time constraints, which was compensated for with accurate qualitative analysis.

The results of this study provide an artifact, which are the design principles and guidelines. They are usable for future work in implementing a gamified MES. The artifact could be used to inform technical prototyping. Further research could focus on implementing, operationalizing, and evaluating the artifact. This research did not include an analysis of company goals or how the wider company, including team leads and management roles, can benefit from gamification of MESs. Additionally, further research is needed to explore how a gamified MES can be integrated with ERP, CRM, HR systems, and quality assurance systems to provide more varied, effective, and detailed feedback.

References

Aarnos, E. (2018). Kouluun lapsia tutkimaan: Havainnointi, haastattelu ja dokumentit. In R. Valli (Ed.), Ikkunoita tutkimusmetodeihin 1: Metodin valinta ja aineistonkeruu: Virikkeitä aloittelevalle tutkijalle (pp. 147–160). PS-kustannus. Retrieved 2023-11-07 from https://www.ellibslibrary.com/book/978-952-451-516-0/ikkunoita-tutkimusmetodeihin-1-metodin-valinta-ja-aineistonkeruu-virikkeita-aloittelevalle-tutkijalle

Alavesa, P., Laitalainen, I., & Immonen, M. (2019). Context Defined Aspects of Gamification for Factory Floor. *2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games)*, 1–2. https://doi.org/10.1109/VS-Games.2019.8864527

Bartle, R. (1996). Hearts, clubs, diamonds, spades: Players who suit MUDs. *Journal of MUD Research*, *1*(1), 19.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77–101. https://doi.org/10.1191/1478088706qp063oa

Chen, X., & Voigt, T. (2020). Implementation of the Manufacturing Execution System in the food and beverage industry. *Journal of Food Engineering*, *278*, 109932. https://doi.org/10.1016/j.jfoodeng.2020.109932

Chou, Y. (2019). Actionable Gamification: Beyond Points, Badges, and Leaderboards. Packt Publishing Ltd.

Coonradt, C. A., & Nelson, L. (2007). *The Game of Work*. Gibbs Smith.

Csikszentmihalyi, M. (2014). Flow and the Foundations of Positive Psychology: The Collected Works of Mihaly Csikszentmihalyi. Springer Netherlands. https://doi.org/10.1007/978-94-017-9088-8

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. https://doi.org/10.1145/2181037.2181040

Emond, J., & Steins, C. (2011). Technical Documentation. In J. Emond & C. Steins (Eds.), *Pro Web Project Management* (pp. 89–116). Apress. https://doi.org/10.1007/978-1-4302-4084-6_7

Esterberg, K. G. (2002). *Qualitative Methods in Social Research*. McGraw-Hill.

European Commission, Directorate-General for Research and Innovation, M Breque, L De Nul, & A Petridis. (2021). *Industry 5.0 – Towards a sustainable, human-centric and resilient European industry*. Publications Office of the European Union. https://doi.org/doi/10.2777/308407

Regulation 2016/679, Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation) (2016). Retrieved 2023-11-29 from http://data.europa.eu/eli/reg/2016/679/2016-05-04/eng

Farzan, R., DiMicco, J., Millen, D., Dugan, C., Geyer, W., & Brownholtz, E. (2008). *Results from deploying a participation incentive mechanism within the enterprise*. 563–572. https://doi.org/10.1145/1357054.1357145

Fitzpatrick, S., & Marsh, T. (2022). The Dehumanising Consequences of Gamification: Recognising Coercion and Exploitation in Gamified Systems. In *Handbook of Research on Cross-Disciplinary Uses of Gamification in Organizations* (pp. 398–417). IGI Global. https://doi.org/10.4018/978-1-7998-9223-6.ch019

Gagné, M., & Deci, E. (2005). Self-Determination Theory and Work Motivation. *Journal of Organizational Behavior*, *26*, 331–362. https://doi.org/10.1002/job.322

Gibson, J. J. (1977). The theory of affordances. Perceiving, acting, and knowing: Toward an ecological psychology. *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*, 67–82.

Greeno, J. G. (1994). Gibson's affordances. *Psychological Review*, *101*(2), 336–342. https://doi.org/10.1037/0033-295X.101.2.336

Gregor, S., Chandra Kruse, L., & Seidel, S. (2020). The Anatomy of a Design Principle. *Journal of the Association for Information Systems*, *21*, 1622–1652. https://doi.org/10.17705/1jais.00649

Gregor, S., & Hevner, A. (2013). Positioning and Presenting Design Science Research for Maximum Impact. *MIS Quarterly*, *37*, 337–356. https://doi.org/10.25300/MISQ/2013/37.2.01

Hakulinen, L., Auvinen, T., & Korhonen, A. (2015). The Effect of Achievement Badges on Students' Behavior: An Empirical Study in a University-Level Computer Science

Course. *International Journal of Emerging Technologies in Learning (iJET)*, *10*(1), Article 1. https://doi.org/10.3991/ijet.v10i1.4221

Hamari, J. (2013). Transforming Homo Economicus into Homo Ludens: A Field Experiment on Gamification in a Utilitarian Peer-To-Peer Trading Service. *Electronic Commerce Research and Applications*, *12*, 236–245. https://doi.org/10.1016/j.elerap.2013.01.004

Hamari, J., & Eranti, V. (2011). Framework for Designing and Evaluating Game Achievements. 115.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? – A Literature Review of Empirical Studies on Gamification. *2014 47th Hawaii International Conference on System Sciences*, 3025–3034. https://doi.org/10.1109/HICSS.2014.377

Helbig, T., Erler, S., Westkämper, E., & Hoos, J. (2016). Modelling Dependencies to Improve the Cross-domain Collaboration in the Engineering Process of Special Purpose Machinery. *Procedia CIRP*, *41*, 393–398. https://doi.org/10.1016/j.procir.2015.12.123

Helmefalk, M. (2019). An interdisciplinary perspective on gamification: Mechanics, psychological mediators and outcomes: Mechanics, mental mediators and outcomes. *International Journal of Serious Games*, *6*(1), Article 1. https://doi.org/10.17083/ijsg.v6i1.262

Hevner, A. (2007). A Three Cycle View of Design Science Research. *Scandinavian Journal of Information Systems*, *19*.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly*, *28*(1), 75–105. https://doi.org/10.2307/25148625

Huotari, K., & Hamari, J. (2017). A definition for gamification: Anchoring gamification in the service marketing literature. *Electronic Markets*, *27*(1), 21–31. https://doi.org/10.1007/s12525-015-0212-z

Huotari, K., & Hamari, J. (2012, October 3). *Defining Gamification—A Service Marketing Perspective*. ACM J. https://doi.org/10.1145/2393132.2393137

International Organization for Standardization. (2011). Systems and software engineering—Systems and software Quality Requirements and Evaluation (SQuaRE)—System and software quality models (ISO/IEC 25010:2011). Retrieved 2023-09-28 from https://www.iso.org/standard/35733.html

International Organization for Standardization. (2018). *Ergonomics of human-system interaction—Part 11: Usability: Definitions and concepts* (ISO 9241-11:2018). Retrieved 2023-09-28 from https://www.iso.org/standard/63500.html

International Organization for Standardization. (2019). *Ergonomics of human-system interaction—Part 210: Human-centred design for interactive systems* (ISO 9241-210:2019). Retrieved 2023-09-28 from https://www.iso.org/standard/77520.html

Juhila, K. (n.d.). Laadullisen tutkimuksen ominaispiirteet. In J. Vuori (Ed.), *Laadullisen tutkimuksen verkkokäsikirja*. Yhteiskuntatieteellinen tietoarkisto. Retrieved 2023-10-25 from https://www.fsd.tuni.fi/fi/palvelut/menetelmaopetus/kvali/mita-on-laadullinen-tutkimus/laadullisen-tutkimuksen-ominaispiirteet/

Jung, J. H., Schneider, C., & Valacich, J. (2010). Enhancing the Motivational Affordance of Information Systems: The Effects of Real-Time Performance Feedback and Goal Setting in Group Collaboration Environments. *Management Science*, *56*(4), 724–742. https://doi.org/10.1287/mnsc.1090.1129

Keepers, M., Nesbit, I., Romero, D., & Wuest, T. (2022). Current state of research & outlook of gamification for manufacturing. *Journal of Manufacturing Systems*, *64*, 303–315. https://doi.org/10.1016/j.jmsy.2022.07.001

Keepers, M., Nesbit, I., & Wuest, T. (2022). The Classification of Game Elements for Manufacturing. In D. Y. Kim, G. von Cieminski, & D. Romero (Eds.), *Advances in Production Management Systems. Smart Manufacturing and Logistics Systems: Turning Ideas into Action* (pp. 453–460). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-16411-8_52

Keepers, M., Romero, D., Hauge, J. B., & Wuest, T. (2020). Gamification of Operational Tasks in Manufacturing. In B. Lalic, V. Majstorovic, U. Marjanovic, G. von Cieminski, & D. Romero (Eds.), *Advances in Production Management Systems. The Path to Digital Transformation and Innovation of Production Management Systems* (pp. 107–114). Springer International Publishing. https://doi.org/10.1007/978-3-030-57993-7_13

Kim, T. W., & Werbach, K. (2016). More than just a game: Ethical issues in gamification. *Ethics and Information Technology*, *18*(2), 157–173. https://doi.org/10.1007/s10676-016-9401-5

Klevers, M., Sailer, M., & Günthner, W. A. (2016). Implementation Model for the Gamification of Business Processes: A Study from the Field of Material Handling. In T. Kaneda, H. Kanegae, Y. Toyoda, & P. Rizzi (Eds.), *Simulation and Gaming in the Network Society* (Vol. 9, pp. 173–184). Springer Singapore. https://doi.org/10.1007/978-981-10-0575-6_14

Knoblauch, H. (2005). Focused Ethnography. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, *6*(3), Article 3. https://doi.org/10.17169/fqs-6.3.20

Koivisto, J., & Hamari, J. (2014). Demographic differences in perceived benefits from gamification. *Computers in Human Behavior*, *35*, 179–188. Scopus. https://doi.org/10.1016/j.chb.2014.03.007

Koivisto, J., & Hamari, J. (2019). The rise of motivational information systems: A review of gamification research. *International Journal of Information Management*, *45*, 191–210. https://doi.org/10.1016/j.ijinfomgt.2018.10.013

Korn, O. (2012). Industrial playgrounds: How gamification helps to enrich work for elderly or impaired persons in production. *Proceedings of the 4th ACM SIGCHI Symposium on Engineering Interactive Computing Systems*, 313–316. https://doi.org/10.1145/2305484.2305539

Korn, O. (2023). Gamification in Industrial Production: An Overview, Best Practices, and Design Recommendations. In C. Röcker & S. Büttner (Eds.), *Human-Technology Interaction: Shaping the Future of Industrial User Interfaces* (pp. 251–270). Springer International Publishing. https://doi.org/10.1007/978-3-030-99235-4_10

Kumar, J. (2013). *Gamification at Work: Designing Engaging Business Software*. 528–537. https://doi.org/10.1007/978-3-642-39241-2_58

Leng, J., Sha, W., Wang, B., Zheng, P., Zhuang, C., Liu, Q., Wuest, T., Mourtzis, D., & Wang, L. (2022). Industry 5.0: Prospect and retrospect. *Journal of Manufacturing Systems*, *65*, 279–295. https://doi.org/10.1016/j.jmsy.2022.09.017

Lessel, P., Altmeyer, M., Müller, M., Wolff, C., & Krüger, A. (2016). “Don’t Whip Me With Your Games”: Investigating “Bottom-Up” Gamification. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, 2026–2037. https://doi.org/10.1145/2858036.2858463

Liu, D., Santhanam, R., & Webster, J. (2016). Toward Meaningful Engagement: A Framework for Design and Research of Gamified Information Systems. *MIS Quarterly*, *Forthcoming*. https://doi.org/10.25300/MISQ/2017/41.4.01

Locke, E., & Latham, G. (1991). A Theory of Goal Setting & Task Performance. *The Academy of Management Review*, *16*. https://doi.org/10.2307/258875

Magylaitė, K., Kapočius, K., Butleris, R., & Čeponienė, L. (2022). Towards High Usability in Gamified Systems: A Systematic Review of Key Concepts and Approaches. *Applied Sciences (Switzerland)*, *12*(16). Scopus. https://doi.org/10.3390/app12168188

Marczewski, A. (2017). The ethics of gamification. *XRDS: Crossroads, The ACM Magazine for Students*, *24*(1), 56–59. https://doi.org/10.1145/3123756

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370–396. https://doi.org/10.1037/h0054346

Mayer, R. E. (2020). *Multimedia Learning* (3rd ed.). Cambridge University Press. https://doi.org/10.1017/9781316941355

Mekler, E. D., Brühlmann, F., Opwis, K., & Tuch, A. N. (2013). Do points, levels and leaderboards harm intrinsic motivation? An empirical analysis of common gamification elements. *Proceedings of the First International Conference on Gameful Design, Research, and Applications*, 66–73. https://doi.org/10.1145/2583008.2583017

Mersch, H., Schlütter, M., & Epple, U. (2010). Classifying services for the automation environment. *2010 IEEE 15th Conference on Emerging Technologies & Factory Automation (ETFA 2010)*, 1–7. https://doi.org/10.1109/ETFA.2010.5641170

MESA. (1997). MES Explained: A High Level Vision. *Manufacturing Enterprise Solutions Association*. Retrieved 2023-10-11 from https://www.pathlms.com/mesa/courses/24315

Morschheuser, B., Hassan, L., Werder, K., & Hamari, J. (2018). How to design gamification? A method for engineering gamified software. *Information and Software Technology*, *95*, 219–237. Scopus. https://doi.org/10.1016/j.infsof.2017.10.015

Myers, M. D. (2019). Qualitative research in business and management. Sage Publications.

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, *17*(1), 2–26. https://doi.org/10.1016/j.infoandorg.2006.11.001

Nacke, L. E., & Deterding, S. (2017). The maturing of gamification research. *Computers in Human Behavior*, *71*, 450–454. https://doi.org/10.1016/j.chb.2016.11.062

O’Donnell, C. (2014). Getting played: Gamification, bullshit, and the rise of algorithmic surveillance. *Surveillance and Society*, *12*, 349–359. https://doi.org/10.24908/ss.v12i3.5017

Payne, G., & Payne, J. (2004). *Key Concepts in Social Research*. SAGE Publications, Ltd. https://doi.org/10.4135/9781849209397

Peffers, K., Rothenberger, M., Tuunanen, T., & Vaezi, R. (2012). *Design Science Research Evaluation*. *7286*, 398–410. https://doi.org/10.1007/978-3-642-29863-9_29

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A Design Science Research Methodology for Information Systems Research. Journal of Management Information Systems, 24(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Pink, S., & Morgan, J. (2013). Short-Term Ethnography: Intense Routes to Knowing. *Symbolic Interaction*, *36*(3), 351–361. https://doi.org/10.1002/symb.66

Rapp, A., Hopfgartner, F., Hamari, J., Linehan, C., & Cena, F. (2019). Strengthening gamification studies: Current trends and future opportunities of gamification research. *International Journal of Human-Computer Studies*, *127*, 1–6. https://doi.org/10.1016/j.ijhcs.2018.11.007

Riar, M., Morschheuser, B., Zarnekow, R., & Hamari, J. (2022). Gamification of cooperation: A framework, literature review and future research agenda. *International Journal of Information Management*, *67*, 102549. https://doi.org/10.1016/j.ijinfomgt.2022.102549

Robson, K., Plangger, K., Kietzmann, J. H., McCarthy, I., & Pitt, L. (2015). Is it all a game? Understanding the principles of gamification. *Business Horizons*, *58*(4), 411–420. https://doi.org/10.1016/j.bushor.2015.03.006

Rodrigues, L., Pereira, F. D., Toda, A. M., Palomino, P. T., Pessoa, M., Carvalho, L. S. G., Fernandes, D., Oliveira, E. H. T., Cristea, A. I., & Isotani, S. (2022). Gamification suffers from the novelty effect but benefits from the familiarization effect: Findings from a longitudinal study. *International Journal of Educational Technology in Higher Education*, *19*(1), 13. https://doi.org/10.1186/s41239-021-00314-6

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist*, *55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sailer, M., Hense, J. U., Mayr, S. K., & Mandl, H. (2017). How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction. *Computers in Human Behavior*, *69*, 371–380. https://doi.org/10.1016/j.chb.2016.12.033

Schuldt, J., & Friedemann, S. (2017). The challenges of gamification in the age of Industry 4.0: Focusing on man in future machine-driven working environments. *2017 IEEE Global Engineering Education Conference (EDUCON)*, 1622–1630. https://doi.org/10.1109/EDUCON.2017.7943066

Shojaeinasab, A., Charter, T., Jalayer, M., Khadivi, M., Ogunfowora, O., Raiyani, N., Yaghoubi, M., & Najjaran, H. (2022). Intelligent manufacturing execution systems:

A systematic review. *Journal of Manufacturing Systems*, *62*, 503–522. https://doi.org/10.1016/j.jmsy.2022.01.004

Spahrbier, M., Blank, D., & Ziegler, D. (2022). Supporting human monitoring activities in highly automated manufacturing through gamification. *Computers & Industrial Engineering*, *168*, 108049. https://doi.org/10.1016/j.cie.2022.108049

Spradley, J. P. (1980). *Participant Observation*. Holt, Rinehart and Winston.

Suh, A. (2017). Enhancing User Engagement through Enterprise Gamification: Identifying Motivational Affordances. *ICIS 2017 Proceedings*. Retrieved 2023-10-19 from https://aisel.aisnet.org/icis2017/HumanBehavior/Presentations/24

Thuan, N., Drechsler, A., & Antunes, P. (2019). Construction of Design Science Research Questions. *Communications of the Association for Information Systems*, *44*(1). https://doi.org/10.17705/1CAIS.04420

Trinidad, M., Ruiz, M., & Calderon, A. (2021). A Bibliometric Analysis of Gamification Research. *IEEE Access*, *9*, 46505–46544. Scopus. https://doi.org/10.1109/ACCESS.2021.3063986

Tuomi, J., & Sarajärvi, A. (2018). *Laadullinen tutkimus ja sisällönanalyysi* (Uudistettu laitos). Kustannusosakeyhtiö Tammi.

Ulmer, J., Braun, S., Cheng, C.-T., Dowey, S., & Wollert, J. (2020). Human-Centered Gamification Framework for Manufacturing Systems. *Procedia CIRP*, *93*, 670–675. https://doi.org/10.1016/j.procir.2020.04.076

Vaidya, S., Ambad, P., & Bhosle, S. (2018). Industry 4.0 – A Glimpse. *Procedia Manufacturing*, *20*, 233–238. https://doi.org/10.1016/j.promfg.2018.02.034

Vermeulen, H., Gain, J., Marais, P., & ODonovan, S. (2016). Reimagining Gamification through the Lens of Activity Theory. *2016 49th Hawaii International Conference on System Sciences (HICSS)*, 1328–1337. https://doi.org/10.1109/HICSS.2016.168

Wallius, E., Tomé Klock, A. C., Eronen, V., & Hamari, J. (2021). Preconceptions towards gamifying work: A thematic analysis of responses of a maritime logistics organization. *Proceedings of the 24th International Academic Mindtrek Conference*, 128–133. https://doi.org/10.1145/3464327.3464368

Warmelink, H., Koivisto, J., Mayer, I., Vesa, M., & Hamari, J. (2020). Gamification of production and logistics operations: Status quo and future directions. *Journal of Business Research*, *106*, 331–340. https://doi.org/10.1016/j.jbusres.2018.09.011

Wolf, T., Weiger, W. H., & Hammerschmidt, M. (2018). Gamified digital services: How gameful experiences drive continued service usage. 2018-January, 1187–1196. Scopus.

Wolf, T., Weiger, W. H., & Hammerschmidt, M. (2020). Experiences that matter? The motivational experiences and business outcomes of gamified services. *Journal of Business Research*, *106*, 353–364. https://doi.org/10.1016/j.jbusres.2018.12.058

Yeow, J., Ng, P. K., Tan, K., Chin, T., & Lim, W. (2014). Effects of Stress, Repetition, Fatigue and Work Environment on Human Error in Manufacturing Industries. *Journal of Applied Sciences*, *14*, 3464–3471. https://doi.org/10.3923/jas.2014.3464.3471

Zhang, P. (2008). Motivational Affordances: Reasons for ICT Design and Use. *Communications of the ACM*, *51*(11), 145–147. https://doi.org/10.1145/1400214.1400244

Appendices

Appendix 1. Usability recommendations for gamification (adapted from Magylaitė et al., 2022, p. 8)

Generalized Recommendations	Explanation
Learnability	A sub-characteristic of the usability characteristic defined in ISO 25010 standard's product quality model (International Organization for Standardization, 2011).
Provide feedback	Communicating what happens in the system to the user. For example, when the user completes a task, the system should display a message about the completion.
Use familiar vocabulary	Using terms known to intended users.
Ensure actions are relevant to goals	Ensuring that available actions suit the goals, and no irrelevant options confuse the user.
Use modality principle	Using various mediums like visuals and sounds instead of only text, making learning easier for new users (Mayer, 2020).
Provide help to users	Providing useful instructions and hints.
Ensure onboarding	Providing all necessary knowledge of a task before the user begins with it.
Use information segmentation	Presenting information with clear visual structure.
Ensure consistency of elements	Ensuring visuals, terms etc. have the same meaning systemwide.
Provide clear error and warning messages	Ensuring error and warning messages include clear and useful information.

Generalized Recommendations	**Explanation**
Provide challenges that scale with user skills	Making challenges correspond to user skill, so they are not too easy or too difficult.
Ensure easy navigation	Making navigation menus, buttons, links, and user’s path clear and understandable.
General	
Ensure user control and freedom	Making it possible to accomplish tasks in multiple ways and letting the user do as they see fit.
Use signaling principle	Cueing the user to relevant elements.
Ensure aesthetic and minimalist design	Limiting the system’s graphical complexity to what is necessary.
Ensure short response time	Eliminating system delay in response to input.
Provide fatigue management	Giving users tools to manage operation speed and avoiding fixed time limits.
Provide personalization controls	Giving users tools to customize for example looks, localizations etc.
Clearly communicate progress	Representing progress via clear and visible indicators.
Provide narrative	Increasing engagements by providing a fictional story in connection to user actions.
Ensure error prevention	Giving hints to reduce user errors.
Ensure recognizability of functions	Differentiating system conventions such as buttons and menus with different functions from each other.
Ensure visibility of objects	Creating elements with thought-out placement and size etc.