Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Information Technology and Electrical Engineering
Department of Computer Science

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The Effect of Game Design Elements on Engagement as a Multi-Dimensional Construct in a Serious Game Context

Master's thesis in Natural Science with Teacher Education &
Master's thesis in Informatics
Supervisor: Boban Vesin
Co-supervisor: Michail Giannakos
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Abstract

This research paper examines the effects of game design elements on engagement as a multi-dimensional construct in a serious game for vocabulary learning and retention. This relationship is investigated using self-report measures and log data. We investigate how the introduction of game design elements affects the different dimensions of engagement, namely behavioral, affective, motivational, and cognitive engagement. Furthermore, we look at what elements contribute the most and the least to engagement as a multi-dimensional construct. Lastly, we explore if the benefits of game design elements are limited or enhanced by external factors, such as age, gender, and game experience. To conduct the analysis, we developed a serious game called LetterLink, which includes several game design elements, including an achievement system, leaderboard, streaks, experience points and levels, and different feedback components (pop-up modals, sounds, animations, and statistics). In this research project, we contribute to the term engagement as a multi-dimensional construct and how various game design elements affect engagement. Furthermore, we contribute to the understanding of measuring engagement using multiple methods: log data and self-report measures. Lastly, we propose a serious game with several game design elements, which can be used to learn new words and train to spell in Norwegian.

Our findings suggest that game design elements significantly affect various dimensions of engagement, with different elements contributing to different aspects. For example, *levels* influenced cognitive engagement, while *sound* influenced affective engagement. Surprisingly, *profile statistics*, *leaderboards*, and *confetti animation* did not predict cognitive, motivational, or affective engagement**.** The introduction of game design elements increased overall engagement, including heightened positive affect, increased game participation, and a greater sense of challenge. Gender differences were not observed in the study. However, gaming frequency had an impact on affective and behavioral engagement. Age was found to influence behavioral engagement.

Sammendrag

Denne forskningsartikkelen undersøker effekten av spilldesign-elementer på engasjement som en flerdimensjonal konstruksjon i et seriøst spill for læring og bevaring av ordforråd. Denne sammenhengen undersøkes ved hjelp av selvrapportering og loggdata. Vi undersøker hvordan introduksjonen av spilldesign-elementer påvirker de ulike dimensjonene av engasjement, nemlig atferdsmessig, affektivt, motiverende og kognitivt engasjement. Videre ser vi på hvilke elementer som bidrar mest og minst til engasjement som en flerdimensjonal konstruksjon. Til slutt undersøker vi om fordelene med spilldesign-elementer er begrenset eller forsterket av eksterne faktorer, som alder, kjønn og spillopplevelse. For å gjennomføre analysen utviklet vi et seriøst spill kalt LetterLink, som inkluderer flere spilldesign-elementer, inkludert et prestasjonssystem, leaderboard, streker, erfaringspoeng og nivåer, og forskjellige tilbakemeldingskomponenter (pop-up modaler, lyder, animasjoner og statistikk). I dette forskningsprosjektet bidrar vi til begrepet engasjement som en flerdimensjonal konstruksjon og hvordan ulike spilldesign-elementer påvirker engasjement. Videre bidrar vi til forståelsen av å måle engasjement ved hjelp av flere metoder: loggdata og selvrapportering. Til slutt foreslår vi et seriøst spill med flere spilldesign-elementer, som kan brukes til å lære nye ord og trene på å stave på norsk.

Våre funn tyder på at spilldesign-elementer i betydelig grad påvirker ulike dimensjoner av engasjement, hvor forskjellige elementer påvirker ulike dimensjoner. For eksempel påvirket spilldesign-elementet *nivåer* kognitivt engasjement, mens *lyd* påvirket affektivt engasjement. Overraskende nok feilet *profilstatistikk*, *poengtavler* og *konfettianimasjon* å predikere kognitivt, motiverende, affektiv engasjement. Innføringen av spilldesign-elementer økte det generelle engasjementet, inkludert økte positive følelser, økt spilldeltakelse og en økt følelse at spillet var utfordrende. Kjønnsforskjeller ble ikke observert i studien. Spillernes erfaring med spill generelt hadde imidlertid en innvirkning på affektiv og atferdsmessig engasjement. Alder påvirket spillernes atferdsmessig engasjement.

Acknowledgments

By studying player engagement in serious games, Kristine has gained insights into how gamification can be effectively integrated into the classroom. Understanding the factors that contribute to engagement will be valuable for her, as a teacher, to design and implement engaging educational experiences that promote active participation, motivation, and effective learning outcomes among students.

We would like to express our deepest gratitude to our supervisor, Boban Vesin, from the Department of Computer Science at NTNU in Trondheim, for providing us with constructive input and for sharing your knowledge with us. Thank you for inspiring us and guiding us during both the preparatory project and the work on this thesis.

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Furthermore, we would like to thank our co-supervisor Michail Giannakos, from the Department of Computer Science of NTNU, for helpful insights on conducting our research.

We also want to express our sincere appreciation to all the participants who generously dedicated their time and effort to playing our game and completing the questionnaires. Your invaluable contributions have been crucial in the success of this research endeavor.

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Abbreviations

DBR: Design based research

GDE: Game design elements

GEQ: Game Experience Questionnaire

SDT: Self-determination theory

XP: Experience points

1 Introduction

1.1 Motivation

By studying game design elements and gamification, one can understand how it affects behavior, such as engagement, productivity, and motivation [1]. The insights can be used to contribute to students' motivation and retention in an education context [2, 3, 4], encourage users to be physically active in a health context [5], and contribute to employee productivity in a workplace context [6].

Developers can use the knowledge to design or optimize user experiences [7]. Furthermore, they can more easily retain players and facilitate monetization by implementing game design elements that keep players engaged.

By studying the effects of game design elements and gamification, one can gain insights into potential adverse effects, such as not every player being fully engaged, compromised performance, problems with attitude [8], and potentially fostering a stressful environment [9].

As gamification becomes more prevalent in various industries, research into its impacts can help us further understand how it works, when it is the most effective, and who it is most effective for.

1.2 Background and Problem Statement

The COVID-19 pandemic has expedited the shift to online and hybrid learning, inspiring the development of creative strategies for teachers and students to plan their teaching and learning activities and engage in more flexible and individualized online interactions [10]. This has led to an increased interest in gamification and serious games [11], as the inclusion of game design elements (i.e., points, rewards, and levels) can enrich the learning process and motivate students [10]. Game design elements, such as leaderboards, play an essential role in promoting user engagement [12, 13, 14, 15] by contributing to feelings of competitiveness [16] and allowing users to compare themselves to each other [17]. User engagement in games is one of the most critical constructs because it captures the user's persistence with the activity, curiosity and interest, cognitive strategies, and positive emotions. Knowing the aspects that influence user engagement is critical to ensuring the efficacy of serious games [11].

In a systematic review of measuring engagement in serious games, Hookham & Nesbitt [18] states that when evaluating engagement, it is clear that a vast range of subjective and objective methodologies have been used. Concerning subjective methodologies, thirty-six questionnaires have been used (i.e., the User Engagement Scale, the Game Flow Questionnaire, the Player Experience of Needs Scale, and the Game Experience Questionnaire). In terms of objective methodologies, ten papers used psychological measures such as measuring electronic pulses from muscle activation, electrical activity in the brain, heart rate changes, and the physical movement of eyes, posture, or limbs. Two papers used only physiological measures, while one used physiological measures in addition to observations in a controlled environment, both indirect and direct. Thirty-seven studies used only questionnaires, while fifty-one used a mix of methodologies. Only twenty-six studies used indirect observations by looking at game metrics. In addition, only 26 out of 107 articles formally defined the term engagement.

This lack of consistency in defining and measuring the construct engagement propagates wide misuse of the term, which leads to questioning the accuracy of the

findings drawn about engagement, as well as the testability of the research questions, which in general lack specificity in defining what engagement is and how it can be measured (i.e., methodological issues).

According to Bernardes et al. [19], further research on strategies and best practices regarding gamification is necessary to utilize it effectively. This is supported by Suh et al. [20], who state that few papers have theorized and empirically assessed how and why game design elements affect engagement, despite the recent increased attention to gamification. Suh et al. [21] further conclude in another paper that a lack of a theoretical framework makes it unclear how gamification affects engagement. In conclusion, there is a lack of understanding of how gamification can be used effectively and how and why game design elements affect engagement.

To summarize, there is a lack of consistency in defining and measuring the construct engagement, and various methods have been used to measure engagement. Furthermore, there is a lack of knowledge on how to utilize gamification effectively and how and why game design elements affect engagement.

To tackle these issues, engagement will, in this thesis, be defined and measured as a multidimensional construct to ensure that all aspects of engagement (i.e., affective, cognitive, behavioral, and motivational) are covered. In addition, by asking participants how motivated they are by the different elements, we try to determine which elements are the most effective for engaging the player. Moreover, we want to explore which game design elements contribute most to users' engagement in serious games so that we can propose design guidelines for what and how to utilize game design elements when developing serious games effectively.

1.3 Goal and Research Questions

1.3.1 Goal

The primary purpose of this study was to generate knowledge of how game design elements added to a serious game can affect the engagement of players, viewed as a multidimensional construct. By identifying the most effective game design elements, developers can design applications that are effective in learning, training, and spelling new words in language learning.

A sub-goal was to develop a serious game with game design elements to investigate if participants can become more engaged when learning new words in a new language by introducing game design elements. A front-end web application written in NextJS, using Firebase Firestore and Firebase Cloud functions, was developed to accomplish this. Technical details are introduced in Section 4.3.

1.3.2 Positioning Our Game as a Serious Game

Stege et al. [22] refers to the term “edutainment”, meaning games that can educate players in addition to entertainment. The authors call such games serious games. Contrary to educational games, serious games are more like traditional video games in terms of the look and feel of the gameplay. Ferdig & Winn [23] states that serious games are similar to entertainment games but are intended to serve a goal other than pure entertainment. Zhonggen [24, p. 1] defines serious games as: “*Different from entertaining games, serious games are designed for an educational rather than an entertaining purpose.*”.

Serious games have been used in different contexts, such as education, rehabilitation, environmental awareness, or physical exercise [25, 26, 27, 28], and can be utilized as an educational tool, replacing traditional methods [29]. Several papers have looked at the relationship between vocabulary learning and retention and serious games:

- Khowaja & Salim [30] devised a framework to design serious games which aim to increase vocabulary among children with autism spectrum disorder (ASD).
- Dinçer & Dinçer [31] looked at the effect of a serious game called X-Plane 11, a flight simulator, on aviation vocabulary.
- Kara [32] investigated the effect between a serious game and vocabulary acquisition from primary school English regarding foreign language students. Results showed that the serious game had a notable effect on vocabulary acquisition compared to traditional instruction.
- Roslin & Hosseinpour Emam [33] looked at the effect between a serious game and vocabulary learning and retention among English foreign language learners. Compared to the control group, the experimental group participant's vocabulary learning and retention significantly increased with the usage of the serious game.

Considering the research in serious games and the elements a serious game requires to be called a serious game, we position our game LetterLink as a serious game. LetterLink offers more than pure entertainment - it offers the opportunity to learn new words and train in spelling in the Norwegian language with another peer. For example, the game can be customized only to allow nouns from the Norwegian Bokmål or verbs from Norwegian Nynorsk. As such, it can be used as an additional tool to traditional classroom language learning. In that regard, we position LetterLink as a serious game because it is designed and developed to serve goals other than pure entertainment, such as

1. LetterLink is a game that can help users, e.g., immigrants in Norway, to increase their vocabulary of Norwegian words (e.g., nouns, verbs, adjectives) by playing and learning new words with another peer.
2. LetterLink can help users to train spelling in Norwegian by playing the game.
3. LetterLink can make learning new vocabulary more engaging and motivating compared to traditional methods such as classroom lectures; thus, it can be used by language teachers as an additional tool to learn and train outside the classroom time.

1.3.3 Research questions

Building on the state-of-the-art research at the intersection between engagement and inclusion of game design elements in serious games, our thesis addressed the following research questions:

RQ1: *How does the introduction of game design elements in a serious game context affect the behavioral, affective, motivational and cognitive engagement of players?*

RQ2: *What specific game design elements in a serious game context contribute the most and the least to engagement as a multidimensional construct?*

RQ3: *Are the potential benefits of game design elements in a serious game context limited to or enhanced in participants depending on external factors such as age, gender, and experience with playing games?*

Many factors come into play when determining what makes a game engaging [34, 35]. Addressing the first research question will contribute to the knowledge regarding the connection between game design elements and engagement. In addition, with the second research question, we will investigate what game design elements affect various dimensions of engagement, such as behavioral, affective, cognitive, and motivational, that in the future might support other researchers to coin the construct engagement as a multidimensional construct that captures individual, interpersonal, and contextual factors related to human learning [36]. Finally, with the third research question, we will investigate if external factors, such as gender, age, and experience with playing serious games, can in some way affect the engagement of the players with LetterLink. Previous research (as shown in Section 2.3) shows that age and gender do not have any influence on player engagement, similar to what Csikszentmihalyi [37] has demonstrated with the Flow theory, i.e., enjoyment is the same regardless of age, social class, or gender; however, players' experience was found that can affect and predict the player's emotional reactions [38].

1.4 Research Approach

In Table 1.1, we present the different phases of working with this thesis. The research was conducted using a design-based research approach, which is further explained in Section 5.1.

Table 1.1: *The different phases of working with this thesis*

Phase	Description
Literature review	To determine what has already been studied, what is missing from the research, and lastly, to assist in defining the problem description and research question for the thesis, a review of the literature in the fields of gamification and engagement was undertaken. See Chapter 2 for more details.
Designing the game	A design for the game created for this thesis was conceptualized using theories from the literature review, inspiration from similar work, and existing solutions. See Section 4.2 for more details.
Research design	Plan of how the experimental study should be done, what data we need, and how it could be analyzed.
System development	Development of the game. See Section 4.3 for more details.
Experimental study	The game developed for this thesis was used in the experimental study. The participants played the two versions of the game over two different weeks - with and without game design elements. See Chapter 5 for more details.
Data analysis	Analyzing the data gathered during the experimental study. See Section 5.6 for more details and Chapter 6 for the results.

1.5 Contribution

Novelty

As a serious game, LetterLink includes a streak feature and strongly focuses on performance and usability, unlike many other serious games considered in this thesis (Chapter 3). Furthermore, various game design elements are included to assess which contributes the most to engagement. Lastly, one can only play against other peers and not a computer. For further explanations, see Section 3.6. Engagement is conceptualized as a multi-dimensional concept, including affective, behavioral, cognitive, and motivational engagement. For further explanations, see Section 2.4.1.

Conceptual

By looking at engagement from a multi-construct point of view, we aim to contribute to the research community in their future endeavors to coin the construct engagement, thus, adding to the conceptual definitions of the term engagement [39].

Empirical

By examining how the introduction of game design elements can increase or decrease the engagement of players, we aim to examine the effect various game design elements have on engagement. Furthermore, by employing the measurement of engagement as a multidimensional construct (i.e., the level at which engagement is conceptualized, observed, and measured), we aim to better understand user engagement, compared to only measuring engagement as a one-dimensional construct.

Operational

To design, implement and develop a serious game with game design elements that will increase engagement among users, compared to having a serious game without game design elements or a serious game with a poor design that lacks game design elements which research has shown leads to decreased engagement.

1.6 Thesis Outline

Table 1.2 presents the structure and different chapters of the thesis.

Table 1.2: *Outline of the thesis structure*

Chapter	Description
2 Background	Introduces the theoretical grounding and theoretical frameworks. Here the literature is reviewed and terminology defined.
3 Related games	Discusses related games, advantages and disadvantages of those, and takeaways for the serious game LetterLink.
4 Concept - LetterLink	Introduces the serious game LetterLink, design decisions, game design elements implemented, and the technological implementation.
5 Methodology	Describes the research strategy, context, instruments, procedure, and analysis conducted. Presents a mapping of each measurement to each dimension of engagement.
6 Results	Present the result and findings from the analyses conducted in the study.
7 Discussion	Discusses the results.

2 Background

This chapter includes the literature review on the current state of the art in serious games and engagement, the definition of terms used, and theoretical grounding and frameworks.

2.1 Theoretical Grounding

To scientifically investigate how game-based elements affect engagement as a multidimensional construct and how engagement as a multidimensional construct can be measured in serious games, we grounded this thesis into Malone's theory of enjoyment [34], the Flow theory [37], and Self-determination theory [40]. The theoretical grounding and the theoretical frameworks, including the GameFlow Model [35], Game Reward System [41], and Gamification Taxonomy [42], will assist us in interpreting the findings from the empirical study we performed concerning the posed research questions.

2.1.1 Malone's Theory of Enjoyment

In 1980, Malone [34] presented a taxonomy of intrinsic motivation of what makes a computer game fun and rewarding for its own sake rather than for some external reward. Intrinsic motivation is when performing an activity is motivating by itself, contrary to extrinsic motivation, where the activity is being done because of an external outcome, for example, money [43]. The taxonomy is emphasized for educational games, but he states that the focus is on what makes them fun rather than educational. Therefore, Malone's enjoyment theory can be suitable for different games, including serious games. The three essential characteristics that make computer games fun are *challenge*, *fantasy*, and *curiosity*. We further elaborate on the *challenge* and *curiosity* characteristics, which are relevant to answering the research questions posed in this thesis.

Challenge

Challenge is essential in creating enjoyable games. Creating a challenging game must provide an appropriate **goal** and **uncertain outcomes** and enhance the player's **self-esteem**. A game should have an appropriate goal to be challenging. Even games with rich and responsive environments may be unpleasant without appropriate goals. For simple games, the goal should be obvious. For complex games, the user should be able to generate goals of appropriate difficulty. The players must get **feedback** on whether they are getting closer to the goal. Practical or fantasy goals are preferable to simply goals of using a skill.

Games are typically dull if the player is sure to win or lose. To introduce uncertain outcomes, the game can **hide information** and selectively reveal it. This seems to trigger curiosity and enrich the challenge of the game. Introducing **randomness** is a final approach to making an uncertain outcome. Challenges and goals are capable of influencing the player's **self-esteem**. Success in any challenging activity can make people feel better about themselves. Conversely, failure can lower self-esteem and decrease the player's desire to play the game again. To maintain the player's self-esteem, the game should find a balance between the player's skill and difficulty level. **Performance feedback**, which tells players if they are moving closer to a given goal, should be presented in a way that does not damage the player's self-esteem.

Curiosity

Malone [34, p. 165] defines curiosity as the following: "*Curiosity is the motivation to learn, independent of any goal-seeking or fantasy-fulfillment.*" He further divides curiosity into two parts, namely **sensory** and **cognitive**.

Malone states that **sensory curiosity** involves how variations or patterns in light, sound, or other sensory stimulations affect the attention-attracting value of an environment. He mentions four ways sensory curiosity can contribute to interest and motivation for a game. It can be used either as decoration, to enhance fantasy, as a reward system, or as a representation system.

Malone [34, p. 166] defines **cognitive curiosity** as the following: “*Cognitive curiosity can be thought of as a desire to bring better ‘form’ to one's knowledge structures*”. By only supplying the players with partial knowledge rather than telling the whole story, they will become motivated to learn more. Feedback should have a surprising effect to engage the player's cognitive curiosity. This can either be accomplished through randomness or have the consistency of the environment being revealed through surprising things.

2.1.2 Flow Theory

The most crucial goal for computer games is player enjoyment [35]. In 1990, Csikszentmihalyi [37] researched what makes experiences enjoyable. He introduced the flow theory in the 70s, researching what people enjoyed, and did activities for pleasure, even without being awarded money or fame. Through his experiments, Csikszentmihalyi discovered that the optimal experience (*flow*) is the same in the world - different activities are described similarly when enjoyed. That enjoyment is the same regardless of age, social class, or gender.

According to Csikszentmihalyi, **flow** happens during work (e.g., performing music, dance, or writing) rather than free time because it relates to learning skills [37]. The activity must be difficult and involve risk to achieve the flow state, as the person needs to stretch their capacity and feel challenged. Flow [35, p. 3] is described as “an experience so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult or dangerous.”. To experience flow, the person's skills must match the challenge associated with the task (see Figure 2.1). If the task is too easy or too difficult, the person will feel bored or anxious respectively.

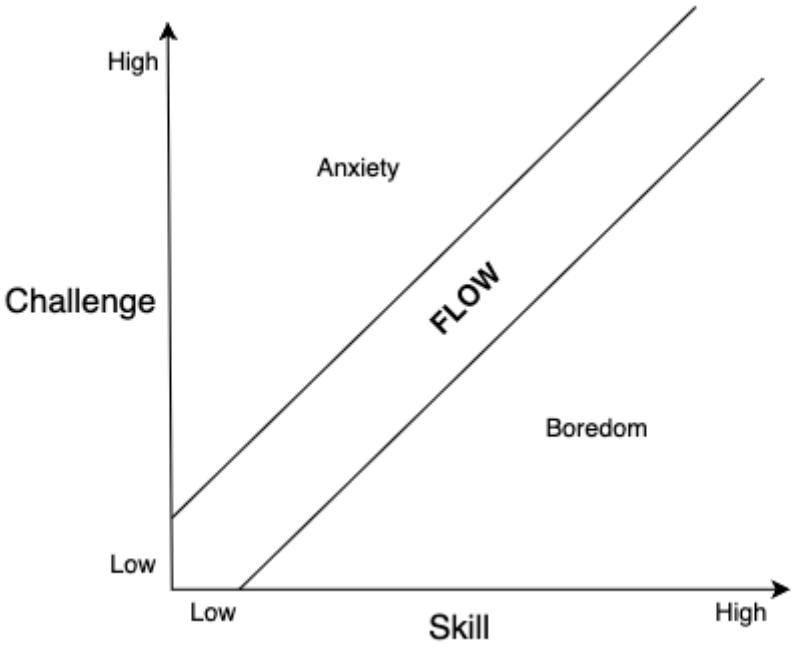


Figure 2.1: *The Flow Model.*

Source: Primary.

2.1.3 Self-determination Theory (SDT)

Self-determination theory (SDT) has previously been used to explain reasons why people play games [44]. SDT states that **autonomy**, **competence**, and **relatedness** are the three basic psychological needs influencing human behavior [40, 44, 45]. These concepts are central to understanding how behavior is initiated and controlled. **Autonomy** refers to feeling liberated from constraints and acting in line with one's sense of self. On the other hand, **competence** is the desire to be challenged and interact efficiently with the surroundings. Lastly, **relatedness** refers to the desire to have a sense of community and to be connected to other individuals and collectives. A study by Ryan et al. [46] indicated that satisfaction with all three basic needs predicted persistent play, while frustration with the exact needs predicted a lack of persistence in play.

SDT distinguishes four types of motivation that underlie human behavior [45]:

- **Intrinsic Motivation** refers to the free, conscious selection of activities for their own sake, that is, for the inherent enjoyment and satisfaction they provide.
- **Identified Regulation** is seen when activity is perceived as self-determined but still subject to external motivation since it is carried out to further an objective rather than for its own sake.
- **External Regulation** involves behaviors driven by external rewards or to avoid punishments.
- **Amotivation** is a lack of motivation, drive or aim, which results in a lack of self-control.

2.2 Theoretical frameworks

2.2.1 GameFlow model

Based on Csikszentmihalyi's research [37], several frameworks for describing flow have been developed. One of these frameworks is the GameFlow model developed by Sweetser and Wyeth [35]. This model comprises eight core elements - **concentration, challenge, skills, control, clear goals, feedback, immersion**, and **social interactions**. Each element consists of several criteria related to Csikszentmihalyi's concept of flow [37] and is conformed to make sense in a game context.

The aim of each element in the GameFlow model is:

- **Concentration** - Games should require concentration, and the player should be able to concentrate on the game.
- **Challenge** - Games should be sufficiently challenging and match the player's skill level.
- **Player Skills** - Games must support the player's skill development and mastery.

- **Control** - Players should feel a sense of control over their actions in the game.
- **Clear Goals** - Games should give players goals at appropriate times.
- **Feedback** - Players must receive appropriate feedback at appropriate times.
- **Immersion** - Players should experience deep but effortless involvement in the game.
- **Social Interactio**n - Games should support and create opportunities for social interaction.

A complete list of GameFlow criteria can be found in Appendix H.

2.2.2 Game Reward System

Rewards are important in games as it positively influences the player's interest and enjoyment [47]. A game should include various reward types, as the different rewards impact the player experience differently [47].

Wang and Sun [41] propose eight forms of rewards. Rewards intend to give the player positive experiences during gameplay and provide social meaning.

1. **Score systems** serve as tools for players to assess themselves and be compared to other players.

2. In an **experience point reward system**, one can typically gain experience points during gameplay, which can be used to level up skills and abilities.

3. **Item granting systems** typically consist of glory or facility rewards, catering to the sensory curiosity of the player, which players and avatars can use. Items boost players' desire to explore the game world and maintain player interest in low-intensity moments. Items have a collecting and social comparison value.

4. **Resources** are valuables that may be acquired and utilized to influence gameplay and are primarily for practical game use or sharing. Examples include life counts or virtual wood and stone.

5. **Achievement systems** involve rewards bound to players/avatars and can be obtained upon completion of stated goals. Achievement systems motivate players to play in more challenging ways, explore the game world, or complete side quests. Badges are examples of such rewards.

6. **Feedback messages** provide instant rewards, like responses to successful actions. Images, music, and video snippets are frequently used as feedback mechanisms.

7. **Plot animations** and pictures to reward the player after important events. Examples include defeating a boss or completing a mission.

8. **Unlocking mechanism** is a form of reward where the player can access previously locked game content, such as new levels or abilities, once certain conditions are met.

2.2.3 Gamification Taxonomy

Toda et al. [42] propose a gamification taxonomy of five dimensions (Figure 2.2). The five dimensions are performance, ecological, fictional, personal, and social. The taxonomy can be used to design and evaluate gamification implementations. Furthermore, considering a lack of naming conventions in gamification research, where badges and trophies are the same concepts [48, 49, 50], using a framework complete with definitions is advantageous.

All five elements from the **performance dimension** and one element from the social dimension are considered relevant to this research project. Due to time and complexity constraints, the remaining elements from the **social dimension** and all from the **fictional**, **ecological**, and **personal** dimensions have **not been included**.

Examples of elements not included are narrative elements from the fictional dimension, cooperation from the social dimension, and economy from the ecological dimension.

Figure 2.2: *Gamification Taxonomy Overview.*
Source: [42]

The performance dimension relates to how the environment and feedback are given to the player. This dimension has five elements:

1. **Acknowledgment** involves badges, medals, trophies, and achievements. It acts as extrinsic feedback and aims to reward players after a set number of actions is completed, for instance, a player winning three games.
2. **Level, skill level, or character level** is an extrinsic hierarchical layer. A player can progress through levels by, for instance, completing achievements.

3. **Progression**, often shown through progress bars, aims to give extrinsic guidance on where a player is in an environment or completion towards a goal.
4. **Points, scores, or experience points** aim to give extrinsic feedback after player actions.
5. **Stats**, also known as information or graphs, provide visual information about the environment, such as how many tasks a user has completed.

The level element becomes especially relevant when connected to the **progression** element [51]. According to the authors, progression is a particularly relevant element. Furthermore, players might feel frustrated or anxious if this element is absent [52]. Dignan further concludes that the lack of statistical elements and information about the environment makes players feel disoriented [52].

The **social dimension** relates to the **interaction between players**. The lack of this dimension leads to players feeling isolated because they cannot interact with each other. The social dimension consists of four elements; however, only one (i.e., competition) is considered relevant for the application of this research project. The game does not include any form of cooperation or titles as a social status to create a hierarchy, so the elements of cooperation and reputation, respectively, are not considered. Furthermore, the game has no form of social pressure to pressure the user, so this element from the social dimension is not included either.

The **competition element** involves **leaderboards**, **scoreboards**, or **player vs. player** overviews. The competition is often tied to a challenge, for instance, obtaining the most points by the end of the month, where players compete against each other.

The competition element can foster a healthy environment of players competing but can also demoralize players who feel they are not performing as expected [42]. When designing the competition element, it is vital not to connect it to any content-based activity, such as a specific skill, or group players together, which might lead to an isolation effect [53, 54].

2.3 Literature Review

Some of the following paragraphs are based on the preliminary report [55].

The main subjects in this project were **engagement**, **game design elements**, and **gamification**. These terms were used in conjunction to gather literature. As new knowledge was obtained, more specific search terms like **intrinsic motivation**, **flow**, and **positive affect** were used. These specific strings were combined with the broad subjects. To find relevant papers, we looked at papers submitted to the following conferences: *ACM CHI Conference on Human Factors in Computing Systems (CHI)*, *Frontiers in Computer Science, Behaviour & Information Technology*, and *International Conference on Human-Computer Interaction (HCI)*. In addition to this, *Google Scholar* was used to conduct the literature review. We also used the snowball search technique, where reference lists (backward snowballing) and citations (forward snowballing) are used to identify new papers and evaluate their relevance [56]. Snowballing was chosen as a search approach for the literature review because it is efficient and reliable [56, 57].

A study by Suh et al. [20] divides user engagement into the sub-dimensions of vigor, dedication, and absorption. **Vigor** represents physical engagement and describes how much effort users are willing to put into completing a task set out by a gamified system and how persistent they are in the face of setbacks. **Dedication** represents emotional engagement and indicates the users' pride, enthusiasm, challenge, and inspiration. **Absorption** represents cognitive engagement and refers to when a person is completely immersed and fully focused on a specific activity, time passes rapidly, and they are unable to disengage. They concluded that game design elements (i.e., *points*, *levels*, *badges/trophies*, and *leaderboards*) lead to user engagement by increasing **needs satisfaction,** which in turn increases **intrinsic motivation** after controlling for age, gender, and education level. Needs satisfaction measures essential psychological needs, including autonomy, competence, and relatedness. The fact that game design elements increase needs satisfaction is also supported in another paper by the same authors [21], which uses the same engagement framework as used by [20].

Klimmt et al. [58] looked for significant differences in **enjoyment** between three different versions of a game (i.e., regular play, redacted perceived effectance, and reduced perceived control). According to the study, the users' enjoyment of games is reduced by decreasing the **immediate feedback** about players' actions. However, lowering the players' control by increasing the game's speed did not reduce the enjoyment felt by the players. This suggests that game enjoyment can arise from being in control or when players struggle to gain control.

Furthermore, Chou et al. [59], using the definition of **flow** by Csikszentmihalyi [37], state that players who feel powerful and in control will have an increased flow experience. As a result, the player controls' impact on player enjoyment seems more complex, while immediate feedback seems essential for the player's subjective game experience. Furthermore, quickly pausing the game and continuing later could enhance their feelings of flow.

Additionally, the presence and absence of **sound** and **music** are found to have an impact on subjective experience, demonstrated by Nacke et al. [15] using the Game Experience Questionnaire (GEQ). When sound was present, positive and natural GEQ dimensions (Flow, Positive Affect, Competence, Immersion, Challenge) received higher subjective ratings, whereas negative GEQ dimensions (Negative Affect, Tension) received lower ratings. Similarly, Levy et al. [60] found that music increased the players' flow experience, stating that music sharpened their focus on the game and made them lose track of time. Thus, the game sound was essential for an enjoyable gaming experience.

Another study [61] found that **playing against humans** in the online game *Neverwinter Nights* evokes increased **flow experience**, **presence**, and **enjoyment** compared to playing against a computer/AI. Thus, a player's game experience seems to be influenced by the type of opponent, where human opponents are favorable. No significant differences were found when controlled for age or playtime frequency.

Research by Chumbley and Griffiths [38] demonstrated that the player's affective state could be affected in different ways by the **reinforcement** qualities of a game. Increasing negative reinforcement increased their frustration and lowered their enjoyment. At the same time, increasing positive reinforcement increased the likelihood of players continuing and returning to play. Additionally, they revealed that the **player's experience level** (time spent on gaming) strongly predicted the player's emotional reactions to computer gameplay, whereas gender and impulsivity had no effect. The questionnaire included three items designed to measure participant inclination to continue and repeat play, where findings indicated no significant differences regarding gender.

Based on the self-determination theory framework, Sailer et al. [62] aimed to analyze game design elements' effect on fulfilling basic psychological needs. The findings showed that the inclusion of **badges, leaderboards,** and **performance graphs** positively affected **task meaningfulness**, in addition to **competence** and **satisfaction**. Furthermore, according to the authors, avatars, meaningful stories, and teammates affected social relatedness. They concluded that gamification is ineffective, but those different game design elements have specific psychological effects.

Kao & Harell [13] found that **badges** and **avatars** promoted player experience and intrinsic motivation during gameplay. The player experience was measured using the PENS scale [46] based on the self-determination theory. Intrinsic motivation was measured using the IMI scale [63] using four dimensions: interest/enjoyment, effort/importance, pressure/tension, and value/usefulness. In addition, having avatars lead to players playing for longer durations. They measured motivated behavior with time played, time testing, and time taking screenshots.

Bai et al. [17] state that, through social comparison, **leaderboards** can be used to increase engagement and motivation. The researchers used the Student Course Engagement Questionnaire [64], which divides engagement into four dimensions: *skill*, *participation/interaction*, *emotion*, and *performance*. According to Bai et al., absolute leaderboards, where all players are shown in the table at once, lead to a

higher degree of feelings of comparison towards others and competitiveness rather than relative leaderboards. In addition, Amo et al. [16] state that leaderboards contribute to feelings of competitiveness, which affects users' engagement.

Bowey et al. [65], using the PENS and IMI scale, looked at how manipulation of **success perception** would affect **player experience**. The player's perception of autonomy, enjoyment, competence, positive affect, and presence was increased by altering the success perception in the leaderboard, compared to manipulated failure. Positive affect, autonomy, and player enjoyment were increased by showing the score.

In an educational game context, Kiili [14] observed that precursors to **flow** were, among other things, **clear goals** and **feedback**, a sense of **control,** and **challenges** matching players' skill levels. Measurements were done using the Flow Scale 1, a scale self-constructed by Killi consisting of nine dimensions: challenge, goal, feedback, control, playability, frame story, concentration, time distortion, and autotelic experience.

Fritz & Avsec [66] looked at predictors of **positive affect** in students during musical activities, such as rehearsals and solo performances. They found that **clear goals**, a **balance between challenge and skill, concentration** on the task, and the task having a purpose were predictors of positive affect. Furthermore, a balance between challenge and skill also predicted negative affect.

Lewis et al. [67] concluded in a project looking at the effects of achievements in a controlled environment that **achievement** showed no strong correlation with intrinsic motivation. The authors [67, p. 2] define intrinsic motivation as: " *the undertaking of an activity for its inherent satisfactions rather than for some separable consequence.*". They conclude that the game itself has more of an effect on intrinsic motivation; however, achievements may lead to more players returning to the game.

In an educational context, Denny [68] discovered that having a **badge-based achievement system** led to a higher quantity of contributions without sacrificing

quality and overall engagement with the tool used in the project. Students participating stated they enjoyed earning badges and having them in the application's user interface. The authors do not define the term engagement itself. The author measured engagement using a survey of seven questions in addition to the following metrics: the number of days students used the tool and the number of questions answered.

Based on the self-determination theory framework, Groening & Binnewies [12] deployed a one-factor between-subjects design to examine the effect the amount of game design elements has on motivation. The participants were divided into four groups representing the number of game design elements: **1)** none, **2)** one (points), **3)** two (points & story) **4)** three (points, story & bonus points). They found that increasing the amount of game design elements increased player motivation and performance. In addition, they found that game design elements would positively affect competence and relatedness from self-determination theory.

2.4 Concepts used in the thesis

2.4.1 Engagement

Engagement has been used to describe numerous constructs, including classroom behavior; students' academic performance; teacher methods in learner-centered classrooms; features of instructional and learning settings intended to start, support, and foster learning; how students interact with educational resources; how students play out cognitive, motivational, affective, metacognitive, and social processes, especially in academic situations [36]. Engagement is an essential construct in education because it has been linked to positive learning outcomes [69] and increased motivation and achievement [39]. Contrary to frustration and boredom, a learner in a state of flow and engagement often exhibits a high degree of satisfaction (i.e., delight), a positive affective state with the complementary effect of broadening the scope of attention [70].

In a game context, engagement influences the player's experience and motivation to continue playing [71]. Engaged players are more likely to be interested in the game and become passionate fans or game enthusiasts [72]. In contrast, players who are not engaged will rapidly lose interest in the game and look for alternative games [73]. Therefore, a game must engage players to maintain higher retention and monetization [74].

Previous studies on engagement have differing views on what engagement is. Azevedo [36] states that engagement is one of the most often misused and overgeneralized terms, widely used without proper definitions. According to a systematic review of engagement in serious games [18], only 26 out of 107 articles formally defined the term engagement. This lack of consistency in defining and measuring the construct engagement propagates wide misuse of the term, which leads to questioning the accuracy of the findings drawn about engagement, as well as the testability of the research questions, which in general lack specificity in defining what engagement is and how it can be measured (i.e., methodological issues).

Mills et al. [75, p. 72] define engagement as "a complex meta-construct with behavioral, affective, and cognitive components that vary both situationally and dispositionally." The **behavioral components** refer to effort and task persistence, whereas **affective components** include valence, arousal, and discrete emotions like curiosity and interest. Attention, concentration, and the use of learning strategies are examples of **cognitive components** of engagement.

In our thesis, we will characterize engagement as a multidimensional construct with a behavioral, affective, and cognitive dimension [75], where each dimension is underpinned by a motivational construct [39]. Although motivation is not identified as a separate dimension of engagement because in research, implicitly or explicitly is often present in the characterization of engagement [39], we are going to include the motivational dimension as a separate dimension due to the following:

1. The core aspects of engagement, e.g., motivation, cognition, and affect, are based on distinctive theoretical models [36, 76, 77]. However, engagement is interchangeably and synonymously used with motivation and flow [78]. Thus, looking at motivation as a separate dimension in our study will allow us to derive insights that can help in the conceptualization of the different aspects (i.e., cognition, motivation, affect) that trigger behavioral, cognitive, affective, and motivational processes during task performance, learning sessions, and so forth while playing serious games.
2. The self-reported measures in the GEQ questionnaire [79] used in our thesis measure the user's perception of cognitive, affective, and motivational beliefs. Thus, we will look for motivational belief as a separate dimension because we have the data for it.

2.4.2 Gamification

Gamification is “the use of game design elements in a non-game context” [80, p. 10]. Non-games are software not considered a game, such as language-learning software, puzzle games, or simulation software. Gamification aims to improve the user experience (UX) and user engagement [81].

2.4.3 Game Design Elements

Game design elements or game elements are features of a game that contributes to the overall game experience. Popular game design elements include *points*, *leaderboards*, and *badges* [82]. Although game design elements are often talked about in the context of gamification, the term is used in this thesis even though the concept is not strictly a non-game.

In the next chapter, we will look closely at related games and analyze which game design elements they implement and why. Next, we will explain which game design elements we have chosen to include in our game.

3 Related Games

Some of the text in the following sections is based on the preliminary report [55].

Scrabble was the main inspiration for the serious game developed in this research project. Scrabble is a well-known physical word game developed by Alfred M. Butts in 1931 [83]. The game has been translated into many languages and used for multiple objectives, such as improving vocabulary and language skills [84, 85]. The game's goal is to arrange letter tiles on a board to create words accepted by a dictionary. The number of people that may play Scrabble ranges from two to four. Each player takes turns building words on the board to earn points based on the letters they use and how they arrange their tile. It includes power-ups on the board, such as a double word score if the player places a word on a given cell (Figure 3.1).

Figure 3.1: *Scrabble board.*

Source: [86]

Scrabble is restricted in the way that it is a physical board game. Online games and digital tools are increasingly becoming a part of our lives. One does not have to physically meet to play in an online game. Furthermore, one can play with friends who live worldwide and even against strangers. These factors make online games far more accessible than physical games. Online games allow for game design elements, such as *feedback* (i.e., sounds and animations), and competitive elements, such as *leaderboards*. The physical board game Scrabble, extended to an online game, was the basis when designing and developing our concept, hereby referred to as LetterLink. Related games were analyzed to gain more inspiration on how to make a performant and user-friendly application, namely WordFeud, Wordle,

WordPlus, Play Scrabble, and Duolingo. Most important, however, by investigating similar games, one can obtain valuable inspiration for what has been done regarding game design elements. One can improve upon and add game design elements that some games lack, creating an application with various elements.

3.1 Wordfeud

Wordfeud [87] is a multiplayer turn-based puzzle game. The game shares many game mechanics with Scrabble. Each player is given seven letter tiles, and the aim is to form words that connect with other words on the board in order to win points. The game is over when all the tiles have been used or when one of the players resigns.

Wordfeud gives **feedback** on how many points a word is worth before the move is submitted and shows the player and opponent's score (Figure 3.2). This corresponds to *feedback messages* from the Game Reward System and *feedback* from the GameFlow framework. The game also contains a **social chat component** that allows users to communicate with one another. This relates to the *social dimension* of the Gamification Taxonomy.

Figure 3.2: Wordfeud in-game.
Source: [88]

3.2 Wordle

Wordle [89] is a popular puzzle game where participants attempt to identify a five-letter word by applying techniques and suggestions to solve a daily challenge. By trying different words, the user is given feedback on how close the word entered was to the word of the day. In total, the user has six attempts to find the word.

To engage users, Wordle displays the **number of games played**, the **win streak** as a percentage, the **current streak**, and the **max streak** (Figure 3.3). These statistics relate to *performance feedback* under challenge, as proposed by Malone. Furthermore, because there is just one word per day, users are likely motivated to return to the game and find it. This challenge relates to *cognitive curiosity*, as proposed by Malone.

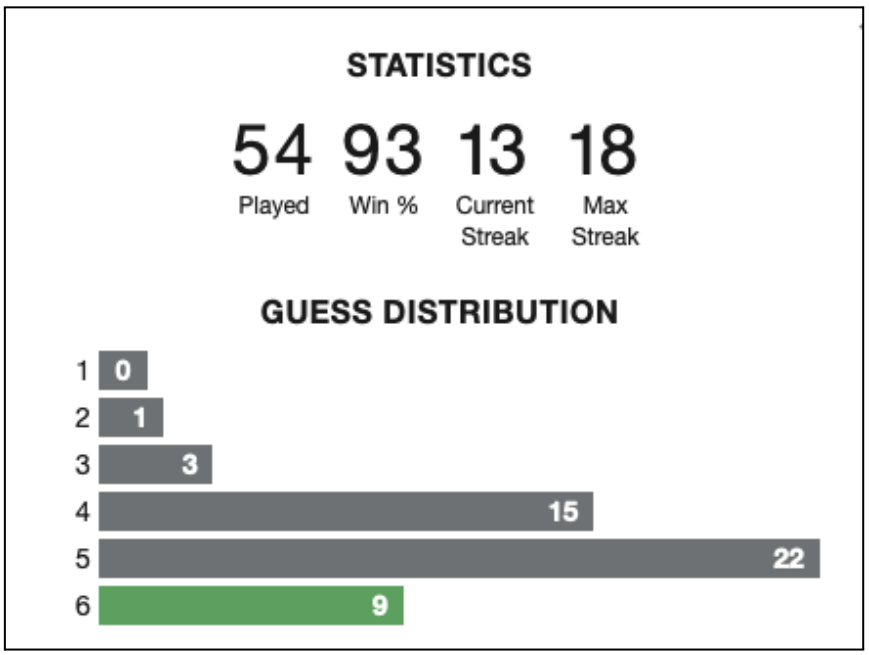


Figure 3.3: *Wordle in-game statistics*.
Source: [89]

3.3 WordPlus

WordPlus [90] is a strategy-based game where players test their vocabulary knowledge and analytical thinking (Figure 3.4). The game begins with a letter centered on the board. During each turn, players must add a new letter to the board and form a word with that letter. Players may create words by combining vertical, horizontal, and diagonal characters. The player receives one for each letter in a word. Finally, the person with the most points wins the game.

The game includes a **leaderboards** feature, corresponding to the Gamification Taxonomy *competition element* and the Game Reward System *scoring system*. Visual feedback is given after a word is placed, which relates to *feedback* from the GameFlow framework and *feedback messages* from the Game Reward System. **Gameplay statistics** are presented, such as the number of games won and lost and the win percentage. This caters to *performance feedback* and *self-esteem*, as proposed by Malone. The game includes **unlockable badges** corresponding to *unlocking mechanisms, item granting* and *achievement systems* from the Game Reward System, and *acknowledgment* from the Gamification Taxonomy. Players can select a **custom grid size** to play on, which relates to *challenges* under the GameFlow framework and Flow theory.

Figure 3.4: *WordPlus in-game*.

Source: [90]

3.4 Play Scrabble

Play Scrabble [91] is an online version of the physical Scrabble board game (Figure 3.5). The game allows players to play against other humans but a computer too.

The game plays a **sound** when placing a letter and a separate sound when the opponent has placed a word. This corresponds to *sensory curiosity* by Malone and *feedback messages* from the Game Reward System. It also relates to *concentration* from the GameFlow framework, which claims that a game should provide stimuli from different sources. The game provides **feedback messages** when an illegal move is made, such as a letter not connected to another. This corresponds to *feedback* from the Game Reward System and GameFlow framework.

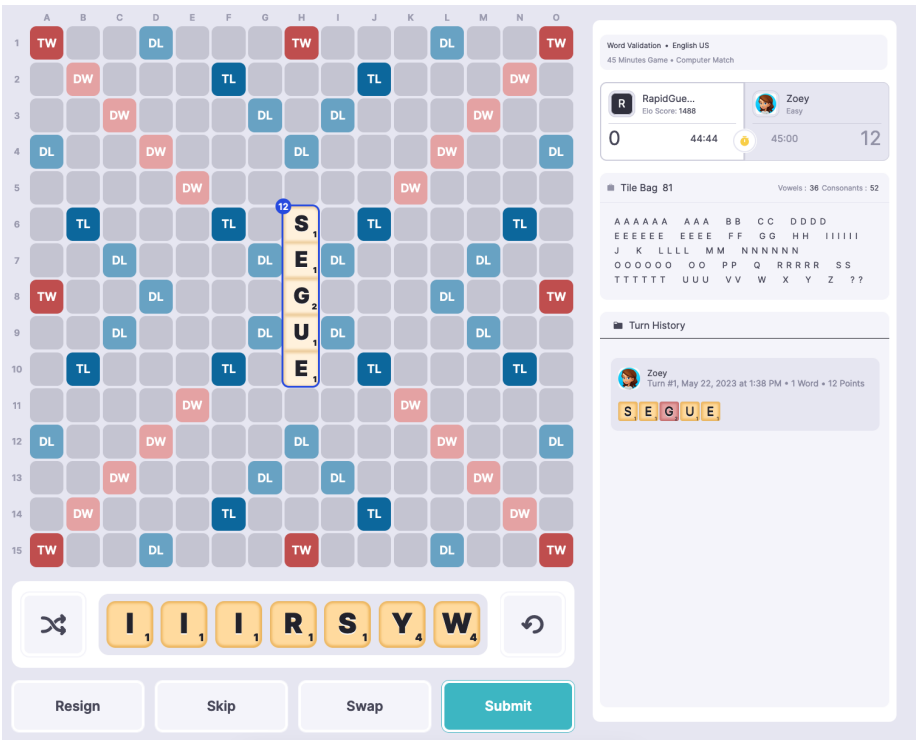


Figure 3.5: *Play Scrabble*.
Source: [91]

3.5 Duolingo

Duolingo is a well-known language-learning app developed by Luis von Ahn and Severin Hacker in 2011 [92] (Figure 3.6). The app uses algorithms to personalize language courses for users depending on their proficiency level and prior performance [93]. The application focuses heavily on gamification through game-design elements, such as **leaderboards**, **streaks**, **achievements**, **sounds**, **experience points**, **levels**, and **feedback messages**, which have been found to increase users' motivation toward learning a second language [94, 95].

After a completed learning session, **feedback animations** are played along with **statistics** on the session, encouraging the player to keep learning. This relates to *feedback* from the GameFlow framework and *feedback messages* from the Game Reward System. The game includes a **leaderboards** feature, corresponding to the Gamification Taxonomy *competition element and* the Game Reward System scoring system. The game includes **unlockable badges** that can be redeemed into so-called gems, which can be used in the shop. This corresponds to *unlocking mechanisms***,** *item granting***,** and *achievement systems* from the Game Reward System and *acknowledgment* from the Gamification Taxonomy. Contrary to the games mentioned above, it includes **streaks** (Figure 3.6), which measure how many consecutive days a user interacted with the app. This corresponds to *performance feedback* by Malone.

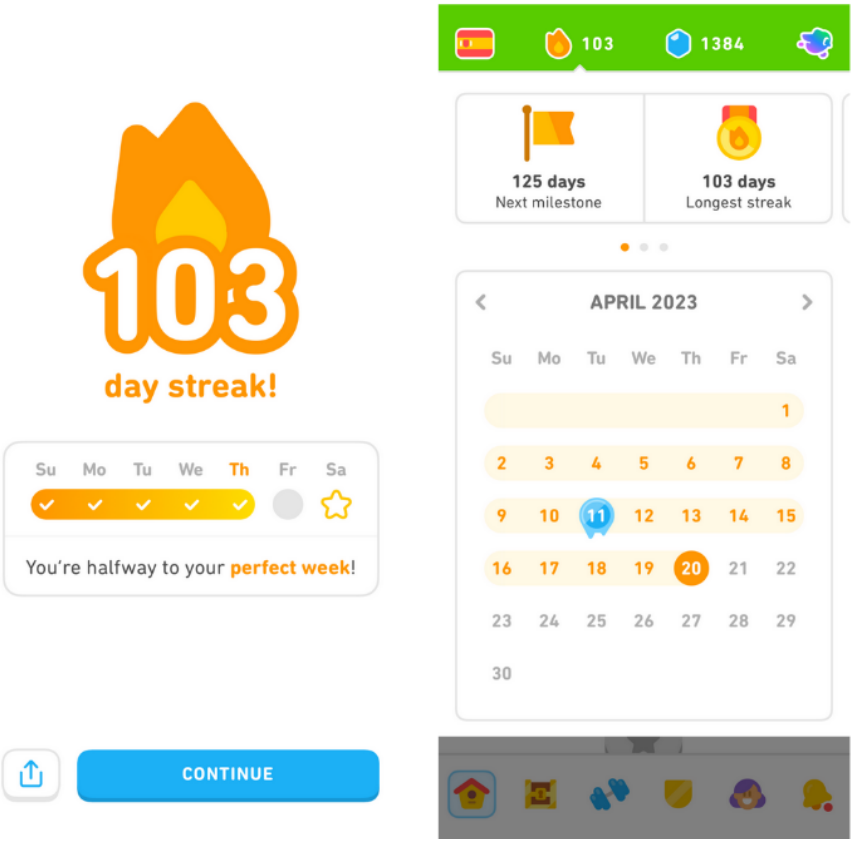


Figure 3.6: *Duolingo Streaks Feature*.

Source: [96]

3.6 Summary and Takeaways

Wordfeud has board tiles with power-ups and a social chat component contributing to engagement, yet it ***lacks a streaks and leaderboards feature***. Wordle has a "one challenge each day" approach, which can encourage users to return to the app. On the other hand, it ***lacks a leaderboard feature***. WordPlus includes various game design elements, but it does ***not have a streaks feature***. Play Scrabble includes sounds and other feedback messages. However, ***no encouraging sound*** is played when the player places a valid word. Furthermore, the game ***does not include leaderboards, streaks, achievements, levels, or experience points***. In addition, the design is not particularly responsive. Duolingo also includes various game design elements. When designing and developing LetterLink, this insight was taken into account. The aim when designing LetterLink was to address the shortcomings mentioned, improve upon features and focus on performance and user experience.

As a serious game, LetterLink is novel in four different ways:

1. The inclusion of a streaks feature

Contrary to Wordfeud, WordPlus, and Play Scrabble, LetterLink includes a streaks feature, which displays how many consecutive days the user has been playing the game. To our knowledge, few papers have looked at the effects of such a streak component on engagement. With this, we want to investigate the effect of a streaks feature on engagement and whether it should be a part of future gamification frameworks.

2. A strong focus on performance and usability

LetterLink focuses strongly on performance and usability. For instance, it aims to improve Play Scrabble's lack of responsive design. To accomplish high performance (i.e., fast initial webpage load and instant response times) in the application, server-side rendering using NextJS and real-time data listeners in Firebase Firestore has been used (see Section 4.3 for more details). To ensure a pleasant user experience [97], Mantine has been used as the component library. Rather than developing user interface components ourselves, we use pre-made, established, and rigorously tested ones. See Section 4.3.4 for further details on Mantine. In addition, regular user testing has been done to ensure features work as expected in terms of performance and user experience.

3. Inclusion of several game design elements to assert which might be the most effective

LetterLink is a more complete serious game, compared to Wordfeud, Wordle, and Play Scrabble, by including several game design elements. To address the shortcomings of Wordle and Play Scrabble, LetterLink includes a leaderboard. LetterLink has a streaks feature, which Wordfeud, WordPlus, and Play Scrabble do not have. LetterLink includes an achievement system, experience point and level system, and proper feedback inspired by WordPlus and Duolingo. Board tiles with power-ups were omitted due to time constraints. However, power-ups were considered a bonus and not vital for the gameplay experience. In addition, the aim is

to determine which of the different game design elements might be the most effective in increasing engagement.

4. No playing against a computer, only humans

In LetterLink, players do not have the option to play against a computer, as one can in Play Scrabble. The fact that one can not play against a computer is intentional because we want to include the social component through peer-to-peer playing, which has been shown to increase feelings of flow, presence, and enjoyment, in contrast to playing against a computer [61]

4 Concept - LetterLink

4.1 The application - LetterLink

The following paragraph is based on the preliminary report [55]

LetterLink is based on the Multiplayer Worlde document in Appendix A. LetterLink is a two-player turn-based word game where players create Norwegian words based on letters they pick. Players are awarded points on how long each valid word is (one point per letter). The winner is the player with the most points after a set number of rounds. Figure 4.1 illustrates a simplified way of how the game works, and Appendix D includes a more detailed description. The project is stored in a GitHub repository [98].

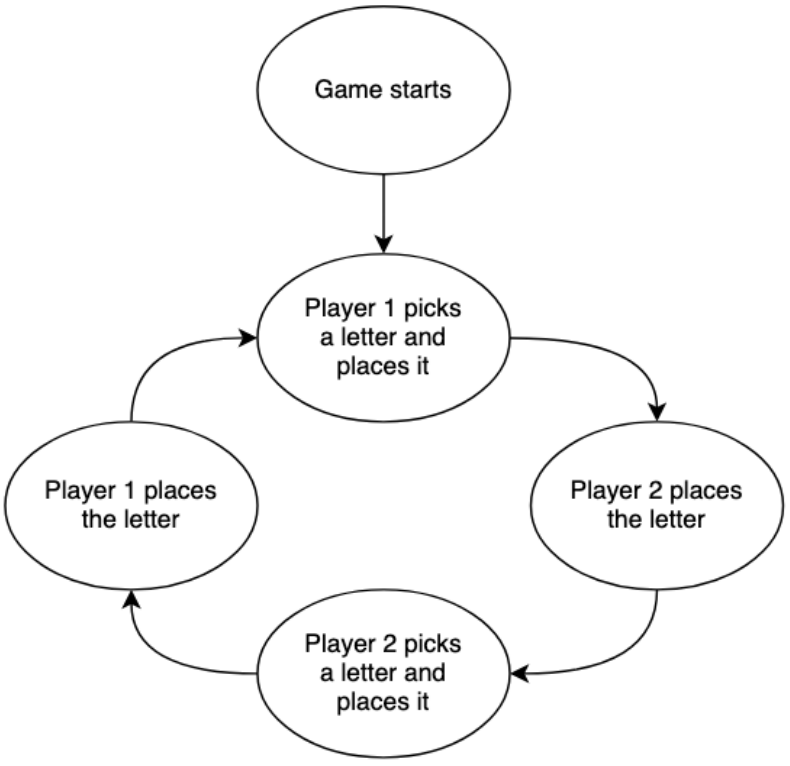


Figure 4.1: *LetterLink game flow*

Source: Primary.

4.2 Design Decisions

Section 4.2.1 describes the design decisions for LetterLink, without the game design elements. The decisions are rooted in theory by Malone, Flow, and the GameFlow framework, as described in Chapter 2. Section 4.2.2 describes the implemented game design elements for LetterLink. The game design elements are rooted in the same theories, in addition to the Game Reward System and the Gamification Taxonomy.

4.2.1 Base Game

To ensure the game is enjoyable to play, as suggested by Malone and in the GameFlow framework, the game has a **clear goal**: to get more points than the opponent by the end of the game. This goal is communicated through the showing of *points* and by telling how many *rounds are left*. In addition, it is communicated in the game manual (Appendix D). The rounds left and points messages also tell how fast players approach the goal. This corresponds to *feedback* under clear goals by Malone and *feedback* from the GameFlow framework.

To enrich the game's challenge and trigger player curiosity, the game implements **hidden information** and **uncertain outcomes**, as proposed by Malone. The opponent's board is hidden, which in turn hides and makes it uncertain how many points the opponent can obtain in the next round. This might increase the user's emotional involvement in the game, as suggested in the GameFlow framework under immersion.

To heighten the player's interest, **randomness**, as suggested by Malone, is a crucial component of the game to heighten the player's interest. Players are given seemingly random letters, picked by the opponent, to place on their own board to create words with.

To avoid demoralizing and ensuring players stay motivated, only neutral or positive feedback is given, in the form of pop-up messages or visual animations, which Malone emphasizes is essential for **self-esteem**.

When a valid word is placed, the cells containing the word are highlighted with a border color to provide visual feedback. This caters to **sensory curiosity** by Malone in addition to **concentration** (stimuli from different sources) and **feedback** from the GameFlow framework.

Players play against other humans, contrary to an AI, promoting social interaction and competition. This relates to the ideas of **social interaction** from the GameFlow framework.

To ensure players are not confused about how to play the game, different descriptive messages, such as “Select a letter”, “It is your opponent's turn,” and “Drag the letter to the grid,” are shown. This relates to **player skills** from the GameFlow framework, regarding that a player should be able to play the game without a manual. Players who are still uncertain how to play can look up the PDF explaining the game and game design elements.

No breaking error messages or gameplay restrictions are in place to ensure players are not demotivated or feel restricted to play in a certain way. This relates to the ideas of **control** from the GameFlow framework.

The game allows the player to adjust the difficulty by choosing which board size to play. The player can choose between a 3x3, 4x4, 5x5, or 6x6 board size. Larger board sizes allow for more complex gameplay, where you have more space to form words, for instance, using words already placed on the board. This relates to **Flow** theory and **challenges** under the GameFlow framework.

4.2.2 Game Design Elements

The game design elements in LetterLink are based on Malone's Theory of Enjoyment, the GameFlow Framework, the Game Reward System, the Gamification Taxonomy from Chapter 2 and related games Chapter 3.

4.2.2.1 Achievement System and Badges

To encourage play and ensure the player stay motivated, LetterLink includes an **achievement system** with corresponding badges (Figure 4.2 and Figure 4.3), built on the ideas of *item granting*, *achievement systems***,** and *unlocking mechanisms* from the Game Reward System and *acknowledgment* from the Gamification Taxonomy. Once the goals for achievement are met, the player gets the corresponding badge. In order to trigger the *cognitive curiosity* of the player, as proposed by Malone, the game **hides badges** for achievement that are not completed.

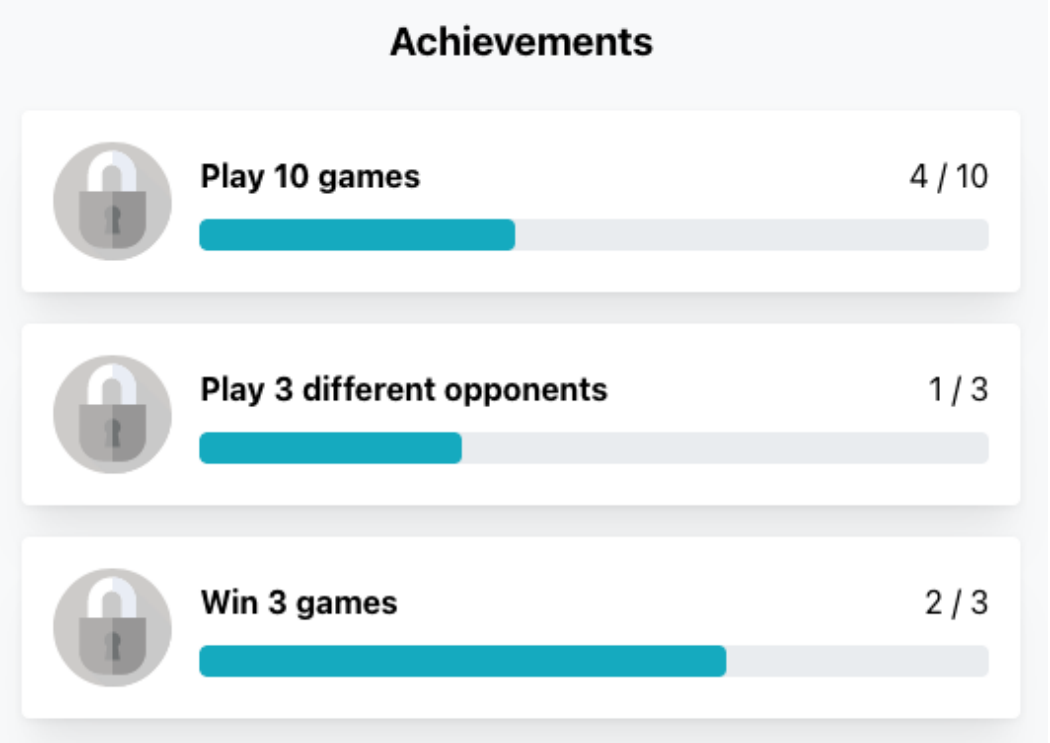


Figure 4.2: *LetterLink Locked Achievements*

Source: Primary.

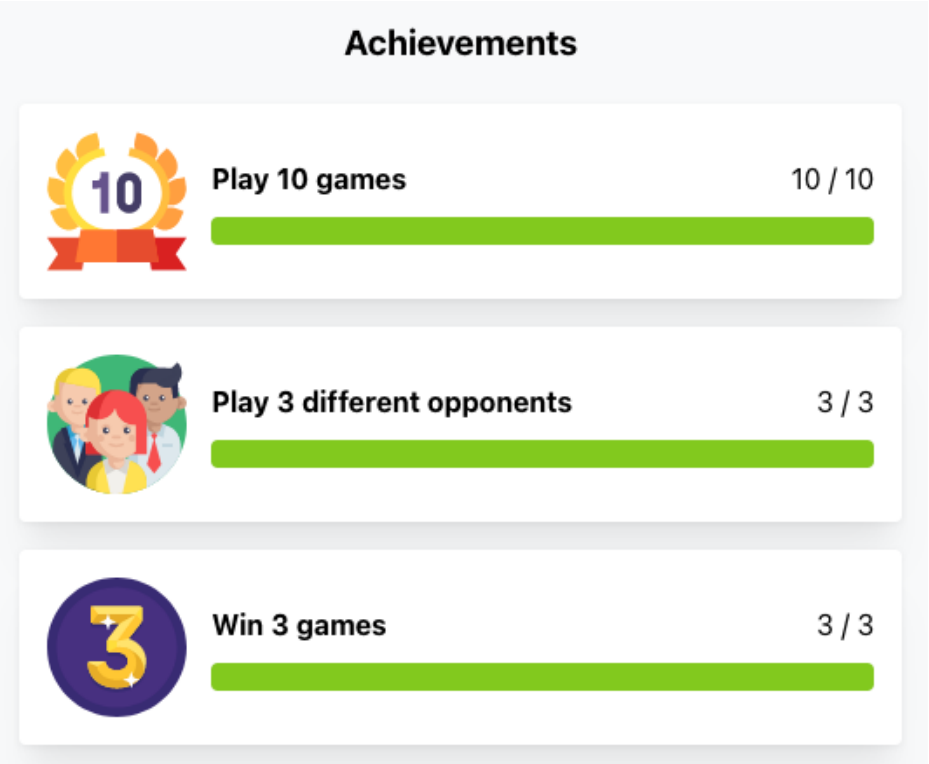


Figure 4.3: *LetterLink Unlocked Achievements*

Source: Primary

4.2.2.2 Leaderboards

In order to promote competition, the game has a **leaderboard feature** (Figure 4.4), which relates to the ideas of a *scoring system* from the Game Reward System and the *competition* element from the Gamification Taxonomy. It is an absolute leaderboard, showing all players at once in one view, as recommended by Bai et al. [17]. In the leaderboard, other players can not see how many games you, as the player, have lost, which is done to prevent a reduction in *self-esteem*. As proposed by Malone, low self-esteem can reduce the player's desire to continue playing.

To foster a healthy competitive environment in LetterLink only **points** and **levels** are displayed in the leaderboard. Players are not classified based on skill or grouped based on skill, which [53, 54] mention might lead to an isolation effect.

Figure 4.4: *LetterLink Leaderboard*

Source: Primary.

4.2.2.3 Streaks

In order to encourage players to play more, the game has a **streaks** feature (Figure 4.5), which is responsible for counting how many days a user was active and displaying the information. A user is registered as active when the game board is rendered at least once daily. This relates to *acknowledgment* from the performance dimension in the Gamification Taxonomy, as it provides **feedback** that recognizes player effort. It also corresponds to *feedback messages* from the Game Reward System.

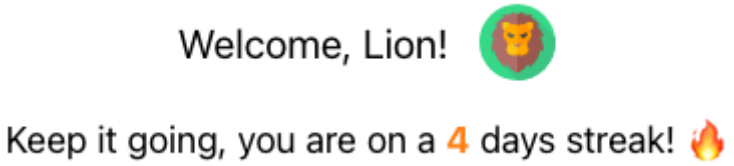


Figure 4.5: *LetterLink Streak*

Source: Primary.

4.2.2.4 Experience Points and Level System

To provide feedback to the player, the game has **experience points** and **level** system (Figure 4.6), which relates to the idea of an *experience point reward system* from the Game Reward System and *level, progression,* and *points* from the Gamification Taxonomy. Everyone is awarded experience points, but players are given more if they do well in the game. Furthermore, playing a game on a larger board will take longer and might be more difficult, but it will award more points because you can place longer words. This relates to the idea that players should be **rewarded for their effort and skill**, from *player skills* in the GameFlow framework. The **name of the next level** is hidden, which tries to stimulate the player's *cognitive curiosity, as Malone suggested*.

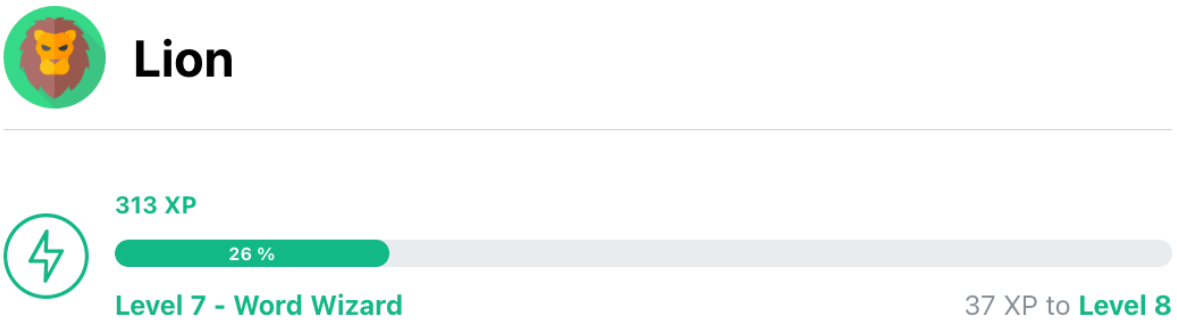


Figure 4.6: *LetterLink experience points and level system*

Source: Primary.

4.2.2.5 Feedback

Modals

In order to provide **feedback** to the player about achievements and levels, modals appear when new achievements are unlocked or the player levels up (Figure 4.7 and Figure 4.8). This corresponds to *feedback messages* from the Game Reward System and *feedback* from the GameFlow framework.

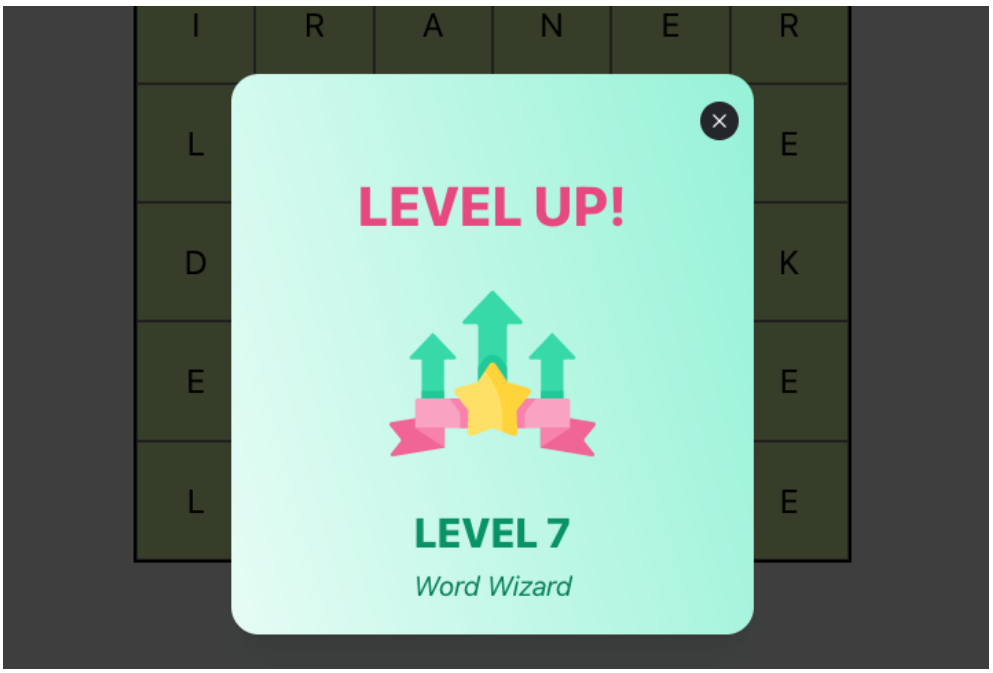


Figure 4.7: *LetterLink Level-Up Modal*

Source: Primary.

Figure 4.8: *LetterLink Achievement Modal*

Source: Primary.

Sound

Sound effects are played to provide feedback to the player when a letter is placed on the grid or when a valid word is formed. This corresponds to the *feedback messages* from the Game Reward System, *sensory curiosity* by Malone and *concentration* (stimuli from different sources), and *feedback* from the GameFlow framework.

Animation

To provide feedback to the player if a game is won, a visual **confetti animation** is shown to the winning player after the game is completed (Figure 4.9). This corresponds to the *feedback messages* from the Game Reward System, *sensory curiosity* by Malone and *concentration* (stimuli from different sources), and *feedback* from the GameFlow framework.

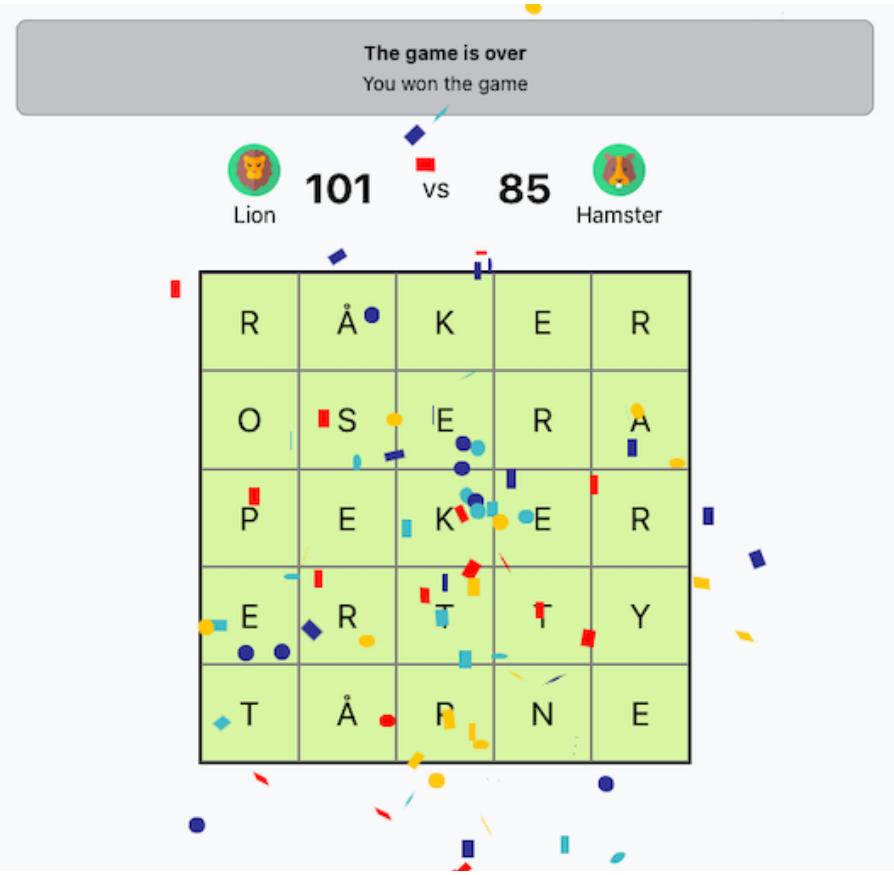


Figure 4.9: *LetterLink Confetti Animation*

Source: Primary.

Statistics

On the profile page, **statistics** are shown to positively encourage the user's self-esteem and tell if he or she is approaching some goal (a high win rate, for instance). This corresponds to *performance feedback* and *self-esteem***,** as proposed by Malone. The **number of games**, **win rate**, **opponent you have won the most**, and the **opponent you have lost the most against** is displayed (Figure 4.10).

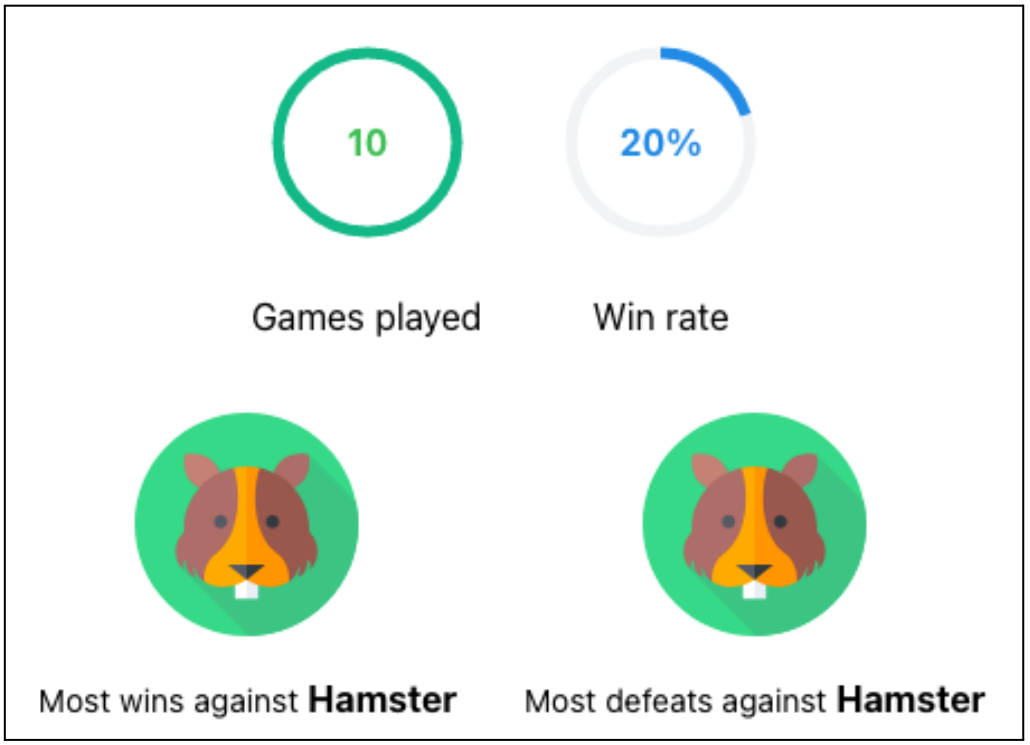


Figure 4.10: *LetterLink Profile Statistics*

Source: Primary.

4.3 Technology Implementation

4.3.1 Design and Development Process

A custom agile development approach was followed during the development process (Figure 4.11). For a given feature, this involved first planning and designing it in Figma, based on the design principles (e.g., consistency; similar buttons should produce similar output) by Don Norman [99]. The feature was then developed and tested. The testing was done by ourselves in addition to weekly testing by externals. Once the feature was ready for production, it was deployed. External people reviewed the features, verifying that they worked as intended.

During development, it was decided not to follow the well-known Scrum methodology. A Scrum methodology includes working with sprints, sprint backlog, daily scrum, and sprint review [100]. Based on previous experience, this worked well for larger teams. In our case, however, we were only two developers. Following the scrum methodology would be ineffective because we cooperated so tightly with design and development, through constant pair programming, for instance.

Due to the continuous testing and integration, we ensured better quality software [101, 102]. In addition, due to early detection and fixing of issues, we reduced the risk of problems that could have severely impacted our application [102]. Last but not least, it made it easier to be flexible and adapt to changes, such as changing a planned feature [101].

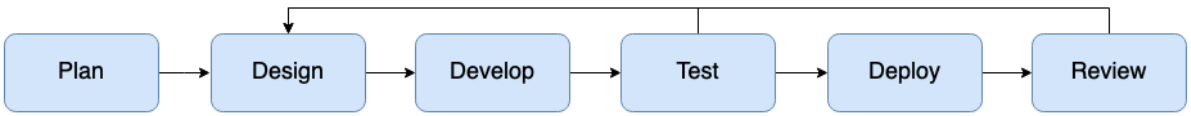


Figure 4.11: *Development process*.
Source: Primary.

4.3.2 Functional Requirements

The following table shows the functional requirements for LetterLink. These were used when designing the component diagram (Figure 4.14).

Table 4.1: *Functional requirements*

ID	Requirement	Priority
FR.1	The user should be able to log in to the application using the provided pre-generated username and password	High
FR.1.2	The user should be able to log out from the application	Low
FR.1.3	The user should be able to withdraw from the study	High
FR.1.4	The user should be able to see all data stored about them	High
FR.1.5	The user should be able to view their profile	
FR.2	The user should be able to propose a game to another user	High
FR.2.1	The user should be able to receive proposals from other users'	High
FR.2.2	The user should be able to accept received game proposals	High
FR.2.3	The user should be able to withdraw game proposals	
FR.3	The user should be able to open an active game	High
FR.3.1	The user should be able to exit an active game	
FR.3.2	The user should be able to make a move and submit it in an active game	High
FR.3.3	The user should be given points when placing a valid word	High
FR.3.4	The user should have points added to their experience points value after a finished game	High
FR.3.5	The user should have the game registered either as won or lost after a finished game	High

FR.3.6	Depending on the game state, progression towards achievements should be updated	High
FR.4	The application should have working game design elements	High
FR.4.1	The *Streak* feature should display how many consecutive days a user has been playing the game	High
FR.4.2	The *Leaderboard* feature should display the highest performing users in descending order	High
FR.4.3	The *Achievement system* feature should display the progress of objectives and badges of completed objectives	High
FR.4.4	The *Experience points and level system* feature should keep track of experience points and levels, and show this on the profile page	High,
FR.4.5	The application should notify through a *Modal* when the user either unlocks an achievement or gains a new level	High
FR.4.6	The application should play a *Sound* when either a letter is placed, or points are gained by placing a valid word	High
FR.4.7	The application should display a *Confetti animation* to the user who has won the game	High
FR.4.8	The game should display *Statistics* in regard to gameplay performance on the user profile page	High
FR.5	The user should be able to compare their performance against others in the *Leaderboard* feature	High
FR.5.1	The user should be able to see the achievements in the *Achievement system*	High
FR.5.2	The user should be able to see their experience points and level in the *Experience points and level system* feature	High
FR.5.3	The user should be notified through a *Modal* when an achievement is unlocked, or a level is gained	High
FR.5.4	The user should hear a *Sound* when a letter or valid word is placed	High

FR.5.5	The user should see a *Confetti animation* if the game was won	High
FR.5.6	The user should see *Statistics* regarding gameplay performance on their profile page	High

4.3.3 Non-functional requirements

The following table describes the non-functional requirements for the application, on which the architectural design decisions were based on.

Table 4.2: *Non-functional Requirements*

ID	Category	Requirement	Priority
NF.1	Usability	Users should not experience any issues relating to the user experience	High
NF.2	Security	The application should use the HTTPS protocol to handle communication between the client and server	High
NF.3	Performance	Once a player makes a move and submits it, the application of the opponent should update in less than one second	High
NF.4	Reliability	The game should handle a minimum of 500 requests per second simultaneously, without any errors or lag	High
NF.5	Availability	During the two weeks where the participants play the game, the application should have a minimum uptime of 99%	High
NF.6	Compatibility	The application should be compatible with both a mobile and desktop web browser	High

4.3.4 Deployment Diagram and Technology Stack

Figure 4.12 depicts our deployment diagram. It consists of a user device that runs a web application on a web browser. The web application talks to a Firebase server[1], which includes an instance of Firebase Firestore[2] to store data and an instance of Firebase Cloud Functions[3] to handle typical backend server tasks, such as generating a profile in the database when the user signs up.

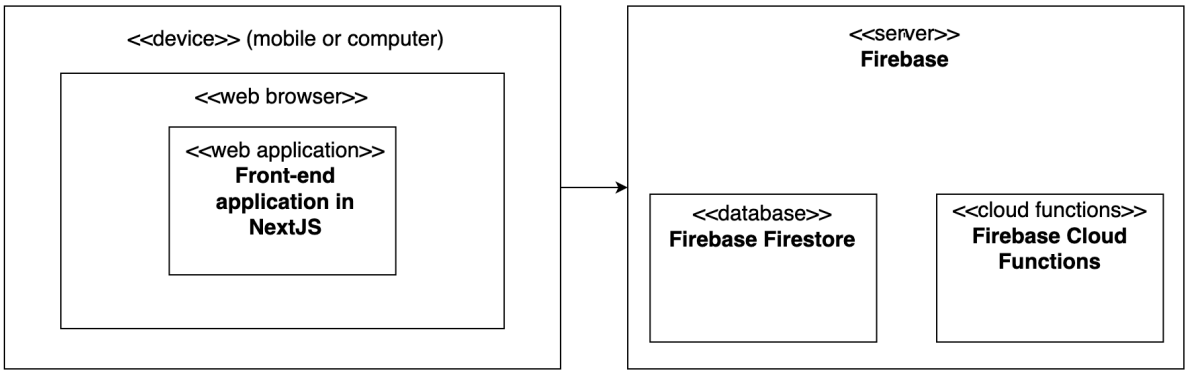


Figure 4.12: *Deployment Diagram*

Source: Primary

The web application is written in the NextJS framework[4] by Vercel[5]. A web application was chosen because of our expertise in developing for the web and the fact that a web application would be accessible on both mobile and desktop. The latter corresponds to **NF.6** - "*The application should be compatible with both a mobile and desktop web browser*." An application working on desktop and mobile was necessary because the threshold for part-taking in the project should be low. However, a native approach would have benefits such as push notifications when a move is made and overall smoother UI interactions. To compensate for the features by making a native approach, the application is a progressive web application. This allows users to install it as a regular application, either on a desktop or mobile.

[1] https://firebase.google.com/
[2] https://cloud.google.com/firestore
[3] https://firebase.google.com/docs/functions
[4] https://nextjs.org/
[5] https://vercel.com/

NextJS was chosen because of its maturity as a web framework and ease of use regarding Server-Side Rendering. The application is hosted using Vercel, which was picked because of its supreme tooling, low costs, and how well it supports NextJS applications. By using an established cloud provider like Vercel to host our application, the chance of the application going down due to a hosting issue would be negligible. This corresponds to **NF.5** - "*During the two weeks where the participants play the game, the application should have a minimum uptime of 99%*". Furthermore, the HTTPS protocol is used to communicate between the client and NextJS server and the client and Firebase API. Encrypted connections make the application far more secure [103] and meet the **NF.2** - "*The application should use the HTTPS protocol to handle communication between the client and server.*".

Mantine[6] was used as the user interface component library. This was chosen to not be required to design and make custom user interface components, which can be highly time-consuming. Mantine components are easily customizable in coloring and appearance and include animations, such as on-button hover and click. Furthermore, the components are well-tested and should not include any bugs. Lastly, Mantine helps make the design responsive, allowing it to scale depending on whether the user is playing on a desktop or mobile. The fact that Mantine was used accomplishes **NF.1** - "*Users should not experience any issues relating to the user experience*."

Google Firebase is the backend service used by the application. This was chosen because of its many built-in features, such as database and authentication services, serverless functions, and analysis tools. Google Firebase services remove the need for a dedicated backend. This allows the application to be serverless, which is not dependent on a dedicated backend, which reduces complexity and hosting costs. Google Firebase is a well-established and stable cloud provider that will have no problem dealing with high amounts of requests. This accomplishes **NF.4** - "*The game should handle a minimum of 500 requests per second simultaneously, without any errors or lag*".

[6] https://mantine.dev/

Firebase Firestore, a NoSQL document-oriented database, reads, writes, deletes, and stores data. This was chosen over Firebase Realtime Database[7] because it structures data in a collection, contrary to Realtime Database, which is a single JSON file. Firestore supports data listeners that trigger when data is updated, changed, or deleted, which allows for a real-time gaming experience when playing LetterLink. This fulfills **NF.3** - "*Once a player makes a move and submits it, the application of the opponent should update in less than one second*."

Firebase Authentication[8] was chosen because it provides an easy-to-set-up and uses an authentication service that integrates easily with Firebase Firestore. Firebase Cloud Functions handles events, such as a user creating an account, which would initially require a dedicated backend.

4.3.5 Application Components and Information Architecture

Figure 4.13 shows how the pages are laid out in the application. To improve the user experience, the application has a flat design, making it easy to find a certain page. This is in contrast to a page only being accessible from another page, for instance.

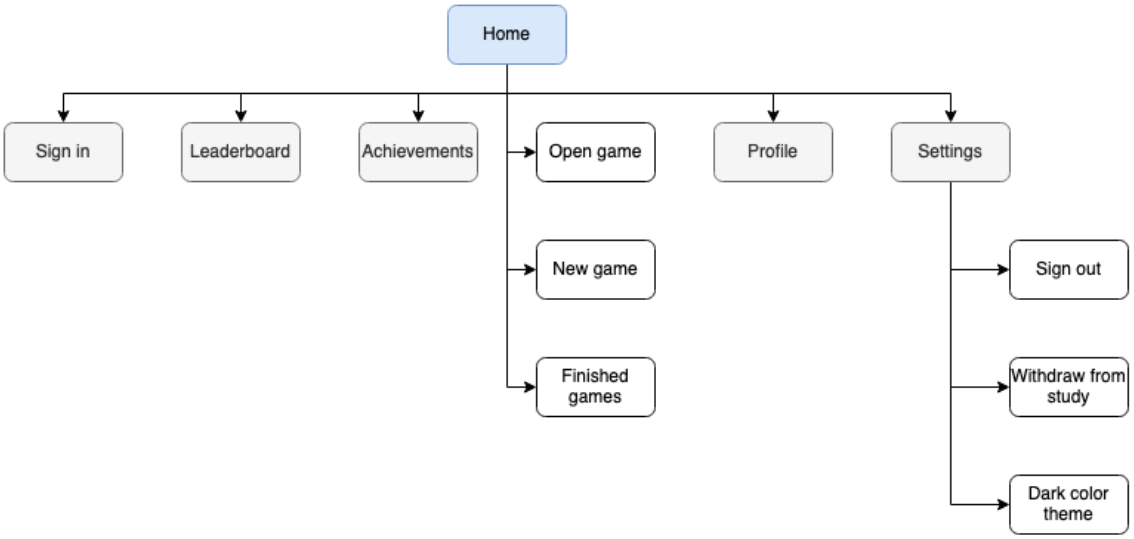


Figure 4.13: *Information Architecture.*

Source: Primary

[7] https://firebase.google.com/products/realtime-database/
[8] https://firebase.google.com/docs/auth

The following table describes each component (page) and its purpose.

Table 4.3: *Component purpose*

Component	Purpose
Sign in */signin*	Allow the user to sign in using the provided username and password to access the application. Users who are not signed in are automatically redirected to this page.
Leaderboard */leaderboard*	Allows the user to compare their performances against other users. *See Section 4.2.2.2 for a detailed description*
Achievements */achievements*	Allow the user to see the progress of achievements and look at badges if one or more achievements are unlocked. *See Section 4.2.2.1 for a detailed description.*
Home */*	Allow the user to start a new game, open up an active game, see finished games, and inspect their streak. *See Section 4.2.2.3 for a detailed description of streaks.*
Profile */profile*	Allow the user to see their level, experience points, games played, and win rate, in addition to the most win-against and most defeat-against data. *See Section 4.2.2.4 and Section 4.2.2.5 for a detailed description.*
Settings */settings*	Allow the user to log out, withdraw from the study and delete all data connected to the user and change to a dark color theme.

4.3.6 Component diagram

Based on the functional requirements from Section 4.3.2, we devised the following component diagram (Figure 4.14). The component diagram describes how the components (i.e., pages, APIs, consoles, database, and serverless functions) communicate. Note that «GDE» refers to the *game design element*.

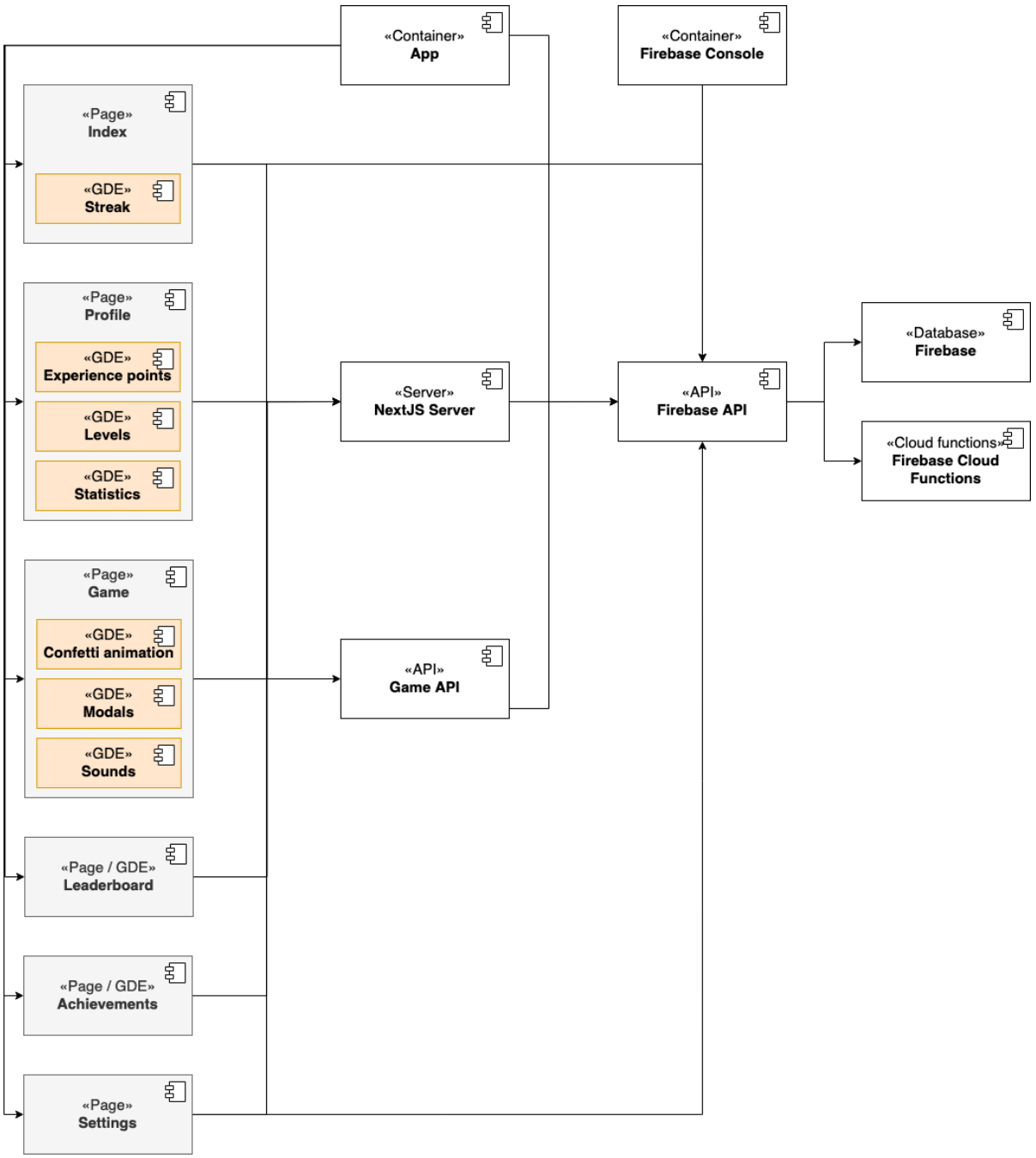


Figure 4.14: *Component diagram*

Source: Primary.

4.3.7 Anonymity

No personal data is stored in the Firebase Firestore database or Google Analytics. Participants log in to the application using a pre-generated email and password. The UID in Firebase Firestore, a random string that uniquely identifies a user, maps to a data row in an Excel sheet containing the email and name of the participant. This Excel sheet is stored securely at NTNU servers behind two-factor authentication. Only the researchers conducting this project, Andreas Amundsen and Kristine Larssen, can access this document. After the project's termination, the Excel sheet is deleted, and all data is stored in Firebase as well. This means that the project fully complies with the Norwegian University of Science and Technology and Sikt rules for gathering and storing personal data.

5 Methodology

5.1 Research strategy

We have adopted Design-Based Research (DBR) [104] as an iterative process that systematically adjusts (e.g., analyze, design) and tests different aspects of a designed context with the purpose of informing practice and generating or improving theory [105]. The first DBR cycle includes playing the game without any gamified elements. This way, we wanted to understand how much the players are engaged without game design elements. The second DBR cycle included an intervention, where the participants were asked to play the game which included gamified elements. The intervention was introduced because we wanted to understand if and how the introduction of game design elements can increase or decrease the engagement of players.

The DBR methodology fits well with our study for the following three reasons: **1)** we need theory to validate the patterns in the data [106], which is why we have grounded our study in the theoretical frameworks presented in Section 2.2; **2)** the context of the study we designed as part of the intervention allows us to acknowledge the situated nature of learning [107]; and **3)** we will try to communicate findings beyond the specific context to create an impact on practice for designing serious games [108].

Building on the current state-of-the-art empirical methods in game-based design research, our thesis addressed the following research questions:

RQ1: *How does the introduction of game design elements in a serious game context affect the behavioral, affective, motivational, and cognitive engagement of players?*

RQ2: *What specific game design elements in a serious game context contribute the most and the least to engagement as a multidimensional construct?*

RQ3: *Are the potential benefits of game design elements in a serious game context limited to or enhanced in participants depending on external factors such as age, gender, and experience with playing games?*

5.2 Context and Participants

We designed a serious game to see if participants could become more engaged when learning new words by introducing game design elements. The main task was to play the online word game (LetterLink) against another human player on their personal device, either desktop or mobile. We asked them first to play the game for one week in the field, whenever and wherever they wanted, as much as they wanted. This version of the game was without the game design elements (see Section 4.2.1). After a week of playing, they were asked to answer a questionnaire. After that, they would play the game for one week in the field, again as much as they wanted, this time with game design elements. They would then answer a new questionnaire. During both weeks, log data containing player actions would be logged and stored for further analysis.

The sample of this study was random people recruited through email. Of the 55 individuals invited to participate in our study, 43 agreed, resulting in a response rate of 78%. Four players were eliminated after the first week of play because they made no moves in the game. Thus 39 participants were included, whereas 21 were men (54%) and 18 were women (46%). The average age was 28 (SD = 10.6) and ranged from 16 to 66 years. Thirteen (33%) participants report that they play games more than three hours per week, eight participants (20%) play games two hours weekly, three participants (8%) play one hour, eight participants (20%) play 30 minutes and seven participants (18%) does not play games weekly.

5.3 Instruments

As mentioned in Section 2.4.1, we will look at engagement as a concept that consists of motivational, cognitive, affective, and behavioral components. Azevedo [36] states that self-reports are ideally suited to measure cognition, affect, and motivational engagement. Therefore, a self-report questionnaire was used to measure the participants' affective, cognitive, and motivational engagement, whereas behavioral engagement was measured through log data.

Cognitive, affective, and motivational engagement

Cognitive and affective engagement was measured using Game Experience Questionnaire (GEQ) developed by IJsselsteijn et al. [79]. GEQ is a self-report tool for an extensive assessment of gaming experience and has been utilized in various contexts in the literature to examine game experience [109, 110, 111, 112]. It consists of 33 items that measure game experience across seven factors, specifically competence, sensory and imaginative immersion, flow, tension/annoyance, challenge, negative affect, and positive affect. The respondents were asked to rank how well the statements (e.g., "*I thought it was fun*" and "*I felt bored*") described how they felt while playing the game on a 5-point Likert scale (1 = *not at all*, 5 = *extremely*).

The motivational impact of game design elements

To measure the motivational impact of game design elements, an adapted version of a self-report survey developed by Chapman and Rich [113] was included. Even though self-report measures might produce insufficient data when measuring outcomes, self-report is specifically appropriate for measuring internal participant impressions, like motivation [36, 109].

For each game design element (leaderboard, achievements, levels, profile statistics, streaks, experience points, and feedback in terms of sounds and confetti animation), the participants were asked to answer the following question on a 5-point Likert scale (1 = *much less*, 5 = *much more*):

> "*In this game, due to [Game design element], I was [much less, less, neither less nor more, more, much more] motivated to play the game compared to playing this game without [Game design element].*"

In addition, to measure the overall impact, participants were asked to respond to the following question on a 5-point Likert scale (1 = *much less*, 5 = *much more*):

> "*Overall, due to the game design elements mentioned previously, I was [much less, less, neither less nor more, more, much more] motivated to play the game compared to playing the game without the game design elements.*"

Behavioral engagement

Log data is a key resource for gaining insights into the players' behavior in online environments [114, 115]. For that reason, behavioral engagement was measured through the log data of each user and game in the Firebase database.

Log data for each user:

- Number of wins, losses, and draw games
- Number of games (not started, active, and ended)
- Number of games they have proposed
- Number of game proposals they have received
- Amount of experience points (points from ended games)
- The total number of points (from both active and ended games)
- Number of days they made a move in the game
- Number of opponents they have ended games with

Log data for each game:

- Players involved in the game
- Points for each player
- Boardsize of the game
- The game status (not started, active or ended).
- If the game was ended, it tracked who won the game

5.4 Variables and mapping

We have mapped all the variables to each of the engagement dimensions (i.e., affective, cognitive, behavioral, and motivational) in order to extend the understanding of user engagement through the multidimensional construct of engagement. The seven constructs used in the GEQ questionnaire cover statements that coincide with various cognitive, affective, behavioral, and motivational aspects of learning. For example, “I felt bored” or “I felt frustrated” coincide with the affective dimension as shown in the research work performed by D’Mello [116]. Thus, we decided to map the seven constructs to the four dimensions that describe the concept of engagement [39], except for the construct of flow, which was left to figure as a flow because of its complex nature, including cognitive, affective, and physical components [117].

A full explanation and overview of all variables used in the thesis can be found in Appendix I.

Self-report measures

Table 5.1 shows the mapping of the Game Experience Questionnaire seven engagement factors to affective, cognitive, and motivational engagement, in addition to flow.

Table 5.1: *Mapping of GEQ’s seven engagement factors*

Constructs	Meaning	Engagement dimension
Flow	Being engrossed in the game, forgot time and connection to outside world	Flow
Positive affect	Feeling happy, good, and enjoyed it	Affective
Negative affect	Feeling bored, tiresome, bad mood	Affective
Tension/annoyance	Being annoyed, irritable, and frustrated	Affective
Sensory and imaginative immersion	Feeling impressed, imaginative, exploring things, aesthetically pleasing.	Affective

Challenge	Feeling pressured and challenged	Cognitive
Competence	Feeling skillful, successful, and good at it	Motivation

Reference for the mapping: positive affect [118], negative affect [119], flow [37], sensory and imaginative immersion [120], Tension/annoyance [116], competence [121] and challenge [122].

Table 5.2 shows how the motivational impact measurement of each game design element is mapped to motivational engagement.

Table 5.2: *Mapping of the motivational impact of game design elements*

Measures	Meaning	Engagement dimension
Confetti animations	How motivated the player was to play the game compared to playing the game without confetti animations	Motivation
Leaderboard	How motivated the player was to play the game compared to playing the game without leaderboards	Motivation
Achievements	How motivated the player was to play the game compared to playing the game without achievements	Motivation
Levels	How motivated the player was to play the game compared to playing the game without levels	Motivation
Sounds	How motivated the player was to play the game compared to playing the game without sounds	Motivation
Profile statistics	How motivated the player was to play the game compared to playing the game without profile statistics	Motivation
Streaks	How motivated the player was to play the game compared to playing the game without streaks	Motivation
Experience points	How motivated the player was to play the game compared to playing the game without experience points	Motivation
Overall motivation	How motivated the player was to play the game compared to playing the game without all game design elements	Motivation

Log data

Table 5.3 shows how the in-game log data measurements are mapped to behavioral engagement.

Table 5.3: *Mapping of the log data*

Measures	Metric Meaning	Engagement dimension
Games	Sum of active and ended games	Behavior
Proposed games list	Sum of unanswered games proposals, both sent and received proposals	Behavior
Proposed games	Number of games the player has proposed	Behavior
Received proposals	Number of game proposals the player has received from other players	Behavior
XP	Amount of experience points gathered in total by the player. One in-game point equals one experience point. Experience points are only added if the game is finished	Behavior
Total points	Sum of experience points and points obtained in unfinished games	Behavior
Lost	Number of games the player has lost a game	Behavior
Wins	Number of games the player has won a game	Behavior
Draw	Number of games the player has a game resulted in draw	Behavior
Opponents	Number of opponents the player has a finished game with	
Not active games	Number of games that have not been started yet, caused by players not yet accepting a proposed game or made any move	Behavior
Active games	Number of active games that are yet to be finished, a game was at least one player has made a move	Behavior
Ended games	Number of ended games	Behavior
Days active	Number of days the player did a in-game move	Behavior

5.5 Data collection and procedure

Data was collected over four weeks, from February to March 2023. The research design and procedure are illustrated in Figure 5.1.

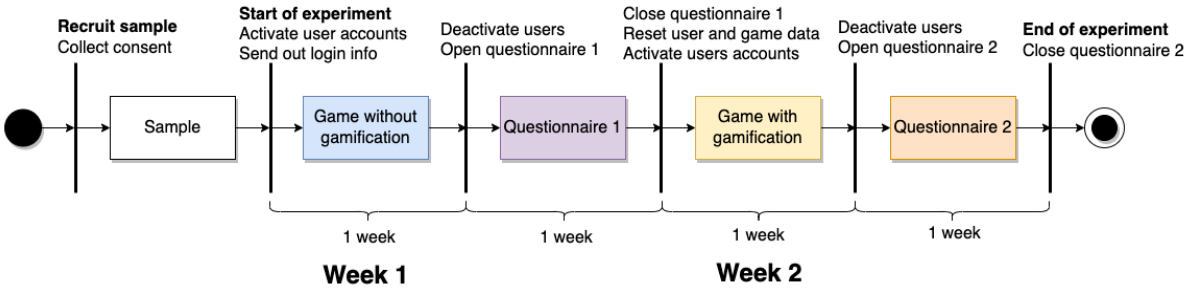


Figure 5.1: *Overview of the data collection*

Source: Primary.

Before the recruitment process, our research project was granted ethical approval by Sikt – Norwegian Agency for Shared Services in Education and Research.

At the start of the first week, each participant received an email (Appendix C1) with their unique anonymous username and password. The username linked questionnaire answers to users in the Firebase database. Throughout the first week, the participants were presented with the basic game version (Section 4.2.1) and encouraged to play the game as much as they wanted. At the end of the first week, all users were disabled so that their in-game behavior could successfully be logged without distractions.

The following week, the participants got an email (Appendix C2) with a link to an online survey (Appendix F) the following week. The online survey was hosted by Nettskjema, a service provided by the University of Oslo [123]. The questionnaire consisted of demographic questions and the Game Experience Questionnaire.

After a week, the questionnaire was closed, and all users were enabled, with their progress (such as active games) being reset. This was done to make the conditions as similar as in the first week. The participants received an email (Appendix C3) with

a reminder that the second and last round of playing the game had started. They were again encouraged to play the game as much as they wanted. In addition, they were informed that the game now contained new features (Appendix E). This week, the game design elements (Section 4.2.2) were enabled. All users were disabled at the end of the week so that their in-game behavior could successfully be logged without distractions.

The following week, the participants got an email (Appendix C4) with a link to another online survey (Appendix G). This survey contained the Game Experience Questionnaire and questions regarding the motivational impact of game design elements.

5.6 Statistical Analysis

The statistical analysis was done using IBM SPSS Statistics version 27. The level of significance was set to $p = .05$.

5.6.1 Average score and reliability measure

Average scores were computed separately for week one and week two for every of GEQ´s seven engagement factors (e.g., flow score week one, flow score week two) [79]. The average score refers to the participant's score on the specific dimension when game design elements are absent and present. See Section 5.4 for a mapping of the factors into the different dimensions of engagement.

Cronbach's Alpha was higher than .70 for almost every factor, indicating high reliability [124], except for the negative affect score in week one ($\alpha = .59$), challenge score in week one ($\alpha = .443$), negative affect score in week two ($\alpha = .61$), challenge score in week two ($\alpha = .59$) and tension score in week two ($\alpha = .59$). However when dealing with psychological constructs like engagement, values lower than .70 can realistically be expected due to the diversity of the constructs being assessed [125].

5.6.2 T-test

Paired sample t-tests were conducted to investigate the effect of game design elements on the different dimensions of engagement, counting GEQ´s seven engagement factors, and the participants' in-game data (i.e., number of games, number of opponents, number of wins and total points). The participants' engagement scores in week 1 (without game design elements) were compared with their engagement scores in week 2 (with game design elements).

Independent samples t-tests were performed to examine the gender and player experience effect on the log data measures (week one and week two), the motivation impact of game design element measures, and the GEQ´s seven engagement factors (week one and week two). Gender was coded 0 = "*male*" and 1 = "*female*". To measure the player experience, we collected background information about the frequency of playing games in general per week, which each of the participants answered in the survey. Considering the frequency, we divided the participants into frequent- and non-frequent players. Players' weekly time spent on games was coded 0 = "*less than 2 hours*" (non-frequent player), 1 = "*more than or equal to 2 hours*" (frequent player).

5.6.3 ANOVA

One-way ANOVAs were conducted to examine age's effect on the log data measures (week one and week two), the motivation impact of game design element measures, and the GEQ´s seven engagement factors (week one and week two). The participants were divided into three age groups (16-24 years, n = 18; 25-39 years, n = 17; 40+ years, n = 4).

5.6.4 Regression analysis

Linear regression analysis was conducted with each of GEQ´s seven engagement factors as the dependent variable and the motivational impact of game design elements as the independent variable. Age, gender, and the players' gaming

frequency (i.e., weekly playing time in general) were used as control variables. The aim was to build a model to predict engagement based on the players' motivation for each game design element. We chose to run a stepwise method for the regression analysis because we were building an exploratory model based on mathematical criteria and not a theory for selecting predictor variables [124]. Theoretically, each framework has game design elements that contribute to increased engagement. However, we wanted to explore which one of the elements based on the data (i.e., data-driven method) contributes the most to engagement increase among the players. The backward elimination method was chosen as it is better than forward elimination when the sample size is small [126]. The analysis uses adjusted R-squared to cross-validate the model, i.e., to observe how well our model generalizes [124].

6 Results

At the end of the first week, a total of 115 games were created, where 15 games had not yet started (i.e., unanswered game proposal, none of the players had made any move yet), 70 games were active (i.e., players had made some moves) and 30 games were ended. In contrast, when the game design elements were introduced at the end of the second week, 150 games were created, which is 35 more games than in the first week. Similar to the first week, 15 of the games were not active. In contrast, 90 games were active, and 45 games were ended, indicating an increase in active and ended games (see Figure 6.1).

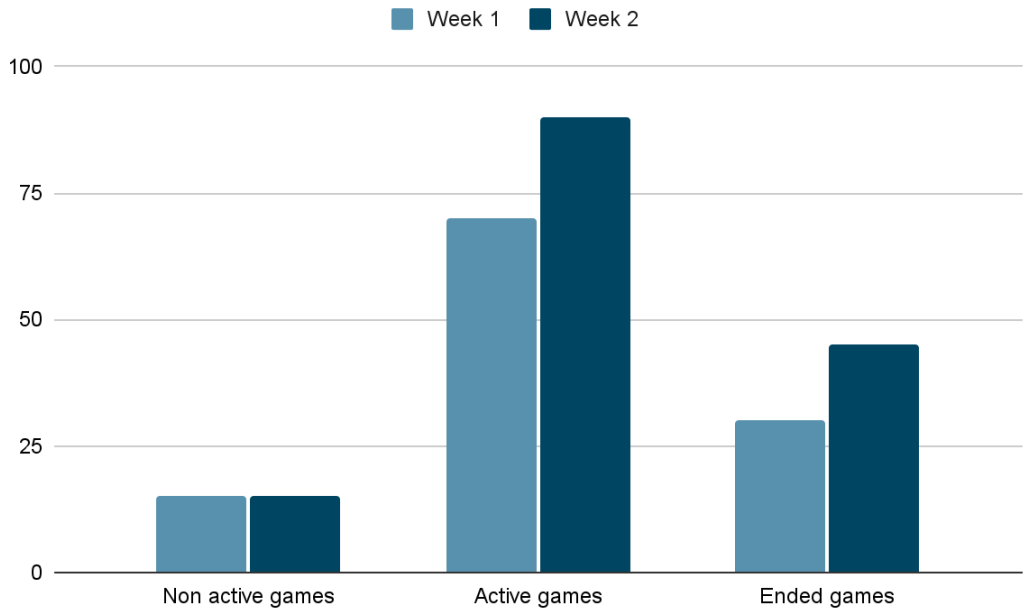


Figure 6.1: *Game status*
Source: Primary.

Figure 6.2 illustrates the number of games of each board size used in the first and the second week. There was an increase in smaller board sizes and a decrease in the use of larger board sizes in the second week when the game design elements were introduced.

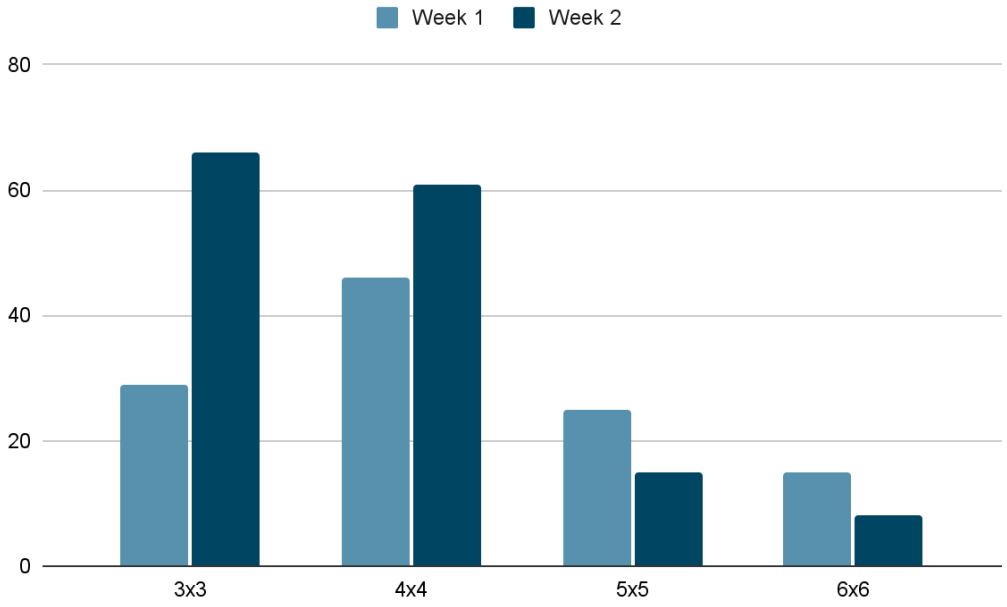


Figure 6.2: *Board Size*
Source: Primary.

6.1 Descriptive statistics

The following tables (Table 6.1, 6.2, and 6.3) present the descriptive statistics and are crucial in exploring the data before further analysis. These tables provide a comprehensive overview of the dataset's main characteristics, allowing us to gain initial insights and understand the data's distribution, trends, and patterns.

When it comes to the GEQ's seven engagement factors, we can see that almost all mean values increased in the second week, except for the mean of tension/ annoyance, which decreased (ΔM = .12), and negative affect, which remained the same but with a minor standard deviation (ΔSD = .10). Positive affect (M_{week1} = 3.55, M_{week2} = 3.78) had the highest mean score, while tension/annoyance (M_{week1} = 1.70, M_{week2} = 1.58) had the lowest.

Table 6.1: *Descriptive statistics - GEQ's seven engagement factors*

	Week one				Week two			
	M	***SD***	**Min**	**Max**	***M***	***SD***	**Min**	**Max**
Positive affect	3.55	.67	2.00	4.80	3.78	.61	2.40	5.00
Competence	3.09	.70	1.40	4.20	3.30	.69	2.00	4.60
Sensory and Imaginative Immersion	2.68	.71	1.50	4.33	3.00	.79	1.50	4.67
Challenge	2.12	.51	1.20	3.20	2.40	.62	1.20	3.80
Flow	2.03	.72	1.00	3.80	2.32	.86	1.20	4.20
Negative affect	1.71	.61	1.00	3.00	1.71	.51	1.00	3.00
Tension/Annoyance	1.70	.79	1.00	4.67	1.58	.61	1.00	3.67

Note. $N = 39$

Regarding the motivational impact of game design elements, we can see that the overall inclusion of game design elements had the highest mean score. When looking at the game design elements separately, the leaderboard ($M = 3.92$) had the highest mean score, whereas sound ($M = 3.26$) had the lowest mean value.

Table 6.2: *Descriptive statistics - Motivational impact of game design elements*

	M	***SD***	**Min**	**Max**
Overall	4.15	.59	3	5
Leaderboard	3.92	.74	3	5
Profile statistics	3.92	.74	3	5
Achievements	3.74	.64	2	5
Experience points	3.72	.61	3	5
Levels	3.67	.66	3	5

Streaks	3.56	.94	2	5
Confetti	3.44	.75	1	5
Sounds	3.26	.79	2	5

Note. *N* = 39

For the behavioral engagement measures, all mean values increased in the second week. In contrast, the highest value of **experience points** (XP) was observed in the first week.

Table 6.3: *Descriptive statistics per user - Log data measures*

	Week 1				**Week 2**			
	M	***SD***	**Min**	**Max**	***M***	***SD***	**Min**	**Max**
Number of games	4.97	2.38	1	11	7.13	4.50	2	21
Number of active games	3.44	2.45	0	9	4.62	3.29	0	14
Number of ended games	1.54	1.68	0	6	2.31	2.43	0	12
Number of non-active games	.67	1.55	0	9	.74	1.09	0	5
Number of wins	.72	.92	0	4	.92	1.40	0	7
Number of lost games	.72	1.05	0	4	.92	1.09	0	5
Number of game proposals sent	2.87	2.91	0	15	3.85	4.39	0	18
Number of game proposals received	2.77	1.91	0	8	3.82	2.36	0	10
Number of opponents	.77	.71	0	2	.92	1.09	0	5
Number of XP	85.90	116.11	0	443	94.85	104.02	0	379
Number of days playing the game	2.69	1.34	1	5	2.74	1.52	1	6

Note. *N* = 39

6.2 T-test

Twenty paired sample t-tests were conducted to investigate the effect of game design elements on the different dimensions of engagement, counting GEQ´s seven engagement factors and the log data (e.g., number of games, number of opponents, number of wins, and total points). The results are presented in Tables 6.4 and 6.5.

Table 6.4: *Paired sample t-test summary for GEQ factors*

			Difference		95% CI of the Differences	
	t	*df*	*M*	*SD*	Lower	Upper
Challenge	-4.10***	38	-.28	.43	-.42	-.14
Sensory and imaginative immersion	-3.39**	38	-.33	.61	-.53	-.13
Flow	-3.02**	38	-.29	.61	-.49	-.10
Positive affect	-2.76**	38	-.23	.52	-.40	-.06
Competence	-1.84	38	-.21	.71	-.44	.02
Tension/Annoyance	1.22	38	.12	.61	-.08	.32
Negative affect	.08	38	.01	.51	-.16	.17

Note. $N = 39$, ** $p < .01$, *** $p < .001$

Table 6.5: *Paired sample t-test summary for log data*

			Difference		95% CI of the Differences	
	t	*df*	*M*	*SD*	Lower	Upper
Games	-4.18***	38	-2.15	3.22	-3.20	-1.11
Active games	-3.99***	38	-1.18	1.85	-1.78	-.58
Received games	-2.75**	38	-1.05	2.38	-1.82	-.28
Draw	-2.51*	38	-.31	.77	-.57	-.06
Opponents	-2.43*	38	-.56	1.45	-1.03	-.10

Proposed games	-1.86	38	-.97	3.27	-2.04	.09
Lost	-.88	38	-.21	1.55	-.68	.27
Wins	-.78	38	-.21	1.64	-.74	.33
Ended games	-.73	38	-.80	2.78	-1.67	.13
Proposed games list	.45	38	.13	1.78	-.45	.71
XP	-.36	38	-8.95	155.45	-59.34	41.44
Not active games	-.28	38	-.08	1.74	-.64	.49
Days active	-.21	38	-.05	1.54	-.55	.45

Note. $N = 39$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

When game design elements were introduced, participants experienced a significant increase in the **challenge** ($d = .66$), flow ($d = .48$), **positive affect** ($d = .42$), and **sensory and imaginative immersion** ($d = .54$). In addition, significant increases were observed in **the number of games** ($d = .67$), **number of active games** ($d = .64$), **number of received game proposals** ($d = .44$), **number of games that ended in a draw** ($d = .40$), and in the **number of opponents per player** ($d = .39$).

Note: Since there is not much text between the tables and to keep off the repetition of reporting t-values, in the text, we will report only the effect size, i.e., Cohen's d, and in the tables will be the rest of the t-statistics.

Gender differences

A total of 51 independent sample t-tests were conducted to examine the differences between **males and females** for behavioral engagement measures (week one and week two), motivation impact of game design measures, and GEQ's seven engagement factors (week one and week two). None of the t-tests yielded a significant difference between the groups, as what has been already shown by most of the research on gender's influence in serious games (for more, please see Section 2.3).

Differences in gaming frequency

A total of 51 independent sample t-tests were conducted to examine the differences between **frequent gamers and non-frequent gamers** as described in Section 5.6.2, regarding behavioral engagement measures (week one and week two), motivation impact of game design measures, and GEQ's seven factors of engagement (week one and week two). There was a significant difference between frequent and non-frequent gamers for **negative affect** ($t(33.60) = -2.10$, $p < .05$, $d = .67$) in the first week and in **the total number of games** ($t(31.32) = -2.21$, $p < .05$, $d = .68$) and **the number of games that ended in draw** $t(35.60) = -2.24$, $p < .05$, $d = .70$) in the second week. Frequent players ($M = 1.89$, $SD = .69$) had a significantly higher negative affect score than non-frequent players ($M = 1.50$, $SD = .42$) during the first week, where there were no game design elements. In addition, frequent players ($M = 8.48$, $SD = 5.26$) were involved in more games than non-frequent gamers ($M = 5.56$, $SD = 2.79$) in week two, with game design elements. Frequent players ($M = .62$, $SD = .74$) also experienced more games that ended in a draw than non-frequent players in the second week ($M = .17$, $SD = .51$).

6.3 ANOVA and age differences

A total of 51 one-way ANOVAs were conducted to examine the differences in engagement measures among three age groups (16-25 years, $n = 18$; 26-39 years, $n = 17$; 40+ years, $n = 4$). The dependent variables included behavioral engagement measures (week one and week two), motivation impact of game design measures, and GEQ's seven engagement factors (week one and week two). The age group was the independent variable. Levene's test was insignificant, suggesting that equal variances could be assumed. Given the unequal group sizes and the need for multiple comparisons, **Gabriel's procedure** was chosen as the post hoc test [124] as it has greater power.

The results revealed significant differences in the behavioral engagement measures between the age groups. Specifically, in the first week (without game design elements), there was a significant difference in **the number of games played** (F(2,

36) = 6.86, $p < .05$, $\eta^2 = .28$). The middle-aged group (25-39) played significantly more games than the oldest age group (40+) ($\Delta M = 3.93$, $p < .01$).

In the second week (with game design elements), significant differences were found in the **number of experience points earned** (F(2, 36) = 4.54, $p < .05$, $\eta^2 = .20$), the **number of lost games** (F(2, 36) = 4.75, $p < .05$, $\eta^2 = .21$), the **number of opponents faced** (F(2, 36) = 5.17, $p < .05$, $\eta^2 = .18$), and the **number of total points achieved** (F(2, 36) = 4.47, $p < .05$, $\eta^2 = .20$). The oldest age group (40+) had a significantly higher amount of experience points than the youngest age group (15-24) ($\Delta M = 129.28$, $p < .05$). The middle-age group (25-39) lost significantly more games ($\Delta M = 1.03$, $p < .05$), had significantly more opponents ($\Delta M = 1.05$, $p < .05$), and a higher amount of total points than the youngest age group (15-24) ($\Delta M = 103.79$, $p < .05$).

6.4 Regression

Seven linear regression analyses were conducted to investigate to what extent the motivation impact of game design elements could predict each of the GEQ´s seven engagement factors. Durbin-Watson was used to investigate independent errors, and collinearity was investigated by Inflation Factor (VIF). Durbin-Watson score varied between 1.64 to 2.27, which indicates weak correlations between residuals as wanted [124]. VIF scores varied between 1.00 and 1.09, thus showing a small degree of collinearity [124]. The requirement for homoscedasticity and linearity was also satisfied, and thus all the assumptions for regression were met. Adjusted R^2 was reported to overcome the r-inflation problem (i.e., adding variables causes a slight increase in the correlation level, regardless of its significance), as it adds a penalty for each variable added [127]. The results are presented in Table 6.6.

Table 6.6: *Linear Regression Analysis Summary for Predicting Engagement*

	B	***SEB***	**β**	***adj. R^2***
1. Flow[a]				.60***
Motivation of Sounds	.65	.11	.58***	
Motivation of Experience points	.57	.15	.38***	
Motivation of Achievements	.35	.14	.26*	
2. Sensory and imaginative immersion[a]				.46***
Motivation of Experience points	.64	.16	.49***	
Motivation of Sounds	.48	.12	.48***	
3. Negative affect[a]				.37***
Overall Motivation of GDE	-.48	.11	-.55***	
Age	.01	.01	.28*	
Weekly time playing games	.10	.04	.28*	
4. Positive affect[a]				.29***
Overall Motivation of GDE	.45	.15	.43**	
Motivation of Experience points	.28	.14	.28	
5. Competence[a]				.21**
Motivation of Experience points	.47	.17	.41**	
Motivation of Sounds	.24	.13	.27	
6. Tension/Annoyance[a]				.08*
Motivation of Streaks	-.21	.10	-.33*	
7. Challenge[a]				.08*
Motivation of Levels	.30	.15	.32*	

Note. N = 39, *p <.05, ** p < .01, *** p < .001, [a] Dependent variable.

When it comes to the **flow** of the players, we can see that there are three game design elements *sound*, *experience points*, and *achievements,* all with a p-value below .05, describing 60% of the variance in flow.

The game design elements that significantly affect **sensory and imaginative immersion** are *experience points* and *sound,* counting for a total of 46% of the variance. Regarding **negative affect**, the player's *age*, *gaming frequency* (weekly time playing games in general), and *overall inclusion of game design elements* were significant predictors, describing 37% of the variance. **Positive affect** was significantly predicted by the *overall inclusion of game design elements* and *experience points*, counting for 29% of the variance.

Important predictors of **competence** are the game design elements, *experience points,* and *sounds*, explaining up to 21% of the variance. We can see that *streaks* are negatively associated with **tension/annoyance**, describing 8% of the variance. Regarding the challenge experience, we can see that *levels* are the most important game design elements, accounting for 8% of the variance.

7 Discussion

The aim of the present thesis was to examine the effects of game design elements on engagement as a multi-dimensional construct in a serious game for vocabulary learning and retention. We have investigated how the introduction of game design elements affects the different dimensions of engagement, what elements contributed the most and the least to engagement, and if the benefits of game design elements are limited or enhanced by external factors, such as age, gender, and game experience.

Our findings indicated that game design elements, in general, had a large ($\beta > .25$) [128] effect on cognitive, affective, and motivational engagement. The different game design elements contributed to different dimensions of engagement (e.g., ***levels*** affect cognitive engagement, whereas ***sound*** affects affective engagement), except for **profile statistics**, **leaderboard***,* and **confetti animation,** which failed to predict any of them (i.e., motivational, cognitive, and affective engagement). The introduction of game design elements increased almost all aspects of engagement (e.g., more *positive affect*, playing *more games*, feeling more *challenged*), except for *negative affect,* which remained the same, and *tension* which decreased. ***No gender difference was observed***. However, the ***player's gaming frequency*** impacted affective and behavioral engagement. In the first week, frequent players experienced more negative affect. When game design elements were introduced in the second week, frequent players were involved in more games and experienced more games that ended in a draw. In addition, the ***player's age*** affected their behavioral engagement.

7.1 Game Design Element’s Effect on Engagement

RQ1: *How does the introduction of game design elements in a serious game context affect the behavioral, affective, motivational, and cognitive engagement of players?*

7.1.1 Affective engagement

The findings suggest that **older people** were more likely to experience **negative affect** while playing the game. Likewise, Bittner and Shipper [129] found that older people (40+) perceived less enjoyment compared to the younger groups (15-38). This is consistent with the fact that gamification's perks diminish with age [48]. The reason may be associated with the fact that older adults are more likely to have less experience with game design elements in a serious context (e.g., education), which may have caused them to struggle with the game and thus experience more negative emotions (e.g., felt bored, tiresome, and had a bad mood).

Furthermore, the regression analysis indicates that people who **spend more time playing games, in genera**l, are more likely to experience **negative affect**. This finding is also supported by the findings from the independent t-tests conducted on frequent vs. non-frequent games discussed in Section 7.3.2. In contrast, Heeter et al. [130] found that *non-games* felt more negative affect when playing a tower defense serious game, suggesting that the type of serious game may influence gamers' negative affect differently. Frequent players might have compared LetterLink to other more comprehensive and polished games, making them feel bored when playing the word game. It is possible that frequent players experienced a greater lack of challenge and stimulation of sensory and cognitive curiosity [34] compared to those games that might have bored them or distracted them.

The **inclusion of game design elements,** in general, was an essential **predictor** of decreasing **negative affect** and increasing **positive affect**. This is unsurprising because different game design elements increase positive affect, like sound [15] and leaderboard [65]. The findings correspond to Groening and Binnewies's [12] conclusion, which argues that increasing the amount of game design elements will increase motivation and performance.

The findings suggest that people motivated by **streaks** were more likely to experience less **tension**. A reason may be in the way streaks introduce a daily goal - to log in to the game every day. This goal can be easier to overcome than other goals, like winning three games or being on the top of the leaderboard. In addition, people motivated by streaks may be satisfied enough as long as the streak is preserved, and they feel less tension, frustration, and irritability than people motivated by competitive elements may be. Further research is needed to evaluate these statements.

Experience points (XP) and **sound** were important **predictors** for **sensory and imaginative immersion**. The fact that sound increases sensory immersion by stimulating the sense of hearing might be explained by sensory curiosity, as proposed by Malone [34]. A similar conclusion was reached by [131, 132, 133]. However, the authors do not specifically mention immersion as sensory or imaginative. The fact that LetterLink provides a “place-a-piece-on-wood” sound when the player places the letter on the board may evoke mental images and increase sensory immersion by transporting the player into the game's fictional universe.

A potential explanation for the association between **experience points** and **sensory and imaginative immersion** could be that experience points are shown as an eye-catching and standout green progress bar under the profile page, which can be aesthetically pleasing to players. The visual input and the sense of progress and accomplishment can enrich the game's sensory experience, making it visually exciting and immersive.

In LetterLink, certain intervals of **experience points** are tied to a certain **level**. For instance, if you have between 300 and 350 experience points, you have achieved *Level 7 - Word Wizard.* Earning experience points to achieve new levels and new level titles may increase excitement and the desire to explore further, which results in a richer and more immersive experience.

7.1.2 Cognitive Engagement

Players motivated by **levels** were more likely to experience **challenge**. This might be because achieving the next level can act as an appropriate **goal**, which according to Malone [34] is essential for a game to be challenging. In order to level up, the player must collect a certain amount of experience points. In LetterLink, experience points are given when a game is finished, and the amount is based on how many valid words the player has placed. To optimize the received amount of experience points to level up, the player has to choose words wisely, which may serve as a cognitive challenge. Also, the higher the level a player achieves brings a recognition of goal attainment and success, which cognitively engages the player to strive for more progress, recognition, and achievement of goals.

7.1.3 Motivational Engagement

The regression analysis indicated that people motivated by **experience points** (XP) were more likely to feel **competent**. As previously argued, experience points can be a measure of skill. Competence includes how successful and skillful a player is. With experience points being a measure of skill, this might have affected this feeling of success and therefore increased the feeling of being a competent player. It can also be explained in light of self-esteem, as proposed by Malone [34], where the gaining of experience points contributes to self-esteem, which increases the feeling of competency.

7.1.4 Behavioral Engagement

When game design elements were introduced, there was an increase in the use of smaller board sizes (3x3 and 4x4) and a decrease in games with larger board sizes (5x5 and 6x6). This may be associated with including achievements, where one goal was to play ten games. Considering the fact that a game on a smaller board takes a significantly shorter time, this might be the reason for the change in board sizes.

Further, the results of the paired sample t-tests suggest that the inclusion of game design elements affected the players' behavioral engagement. When game design elements were included, the players' had more games (specifically active games), game proposals, and unique opponents, and games ended in a draw.

Games (specifically active games), game proposals, and unique opponents

The increase in game proposals and games might be due to the inclusion of **achievements**. As argued before, achievements introduce some goals to overcome and reward the player with a secret badge when it is achieved. This might have motivated the players to reach the goal, either for their own sake (intrinsic motivation) or to unlock the achievements badge. The achievement objectives were *"play ten games," "win three games,"* and *"play against three opponents,*" which encourage the player to be involved in more games and opponents to overcome the challenges and might explain the increase of game proposals, games in general and unique opponents.

Another reason might be the inclusion of **experience points***,* **levels***,* and **leaderboards**. In LetterLink, the leaderboard was implemented with all players shown on the table at once, which may have contributed to greater levels of comparison to others and competition, as proposed by Bai et al. [17]. To be on the top, the player needs to have the highest amount of experience points and, thus, be at the highest level. Therefore, including these game design elements may positively affect the users' motivation and engagement.

Another reason may include the desire to continue playing. Considering that the players were not notified when the opponent made a move, it makes sense that the players sent out more proposals in order to increase their chances of playing the game. By sending out game proposals to several users, they can avoid being dependent only on one player having the time to play. However, there is also the possibility that the increase in games may be because the players were more familiar with the game in the second week. Further analysis, with the inclusion of a control group, is needed to evaluate our results and to exclude the potential risk of repeated measures design [134].

Games ending in draw

A potential reason for an increase in games ending in a draw when game design elements were introduced may be associated with the inclusion of competitive elements like leaderboards. Competitive elements may cause players to concentrate more on defensive strategies than aggressive or risky moves. The players may emphasize preserving their winning percentage (shown on the profile page), which can result in more defensive and cautious gameplay. Players using defensive strategies will calculate their moves carefully, and the fact that both players have the same prerequisites for success (i.e., the same letters and board size) may increase the likelihood of draws.

7.1.5 Flow

The regression analysis indicated that people motivated by **sound**, **experience points** (XP), or **achievements** were more likely to experience a **flow state**. Flow is described as the optimal experience [37], an experience so pleasurable, involving both cognitive, affective, and physical components of engagement [117]. To achieve the state of flow, there must be a balance between the player's skill level and the challenge they are given [37]. Achievements give the player a goal to reach and a challenge to overcome, making an enjoyable gaming experience [34]. In LetterLink, achievements provide the player with clear goals (e.g., winning three games), and different challenges to overcome and give the player feedback on their progress against the goal. This feature corresponds to what Kiili [14] observed as precursors to flow and may explain why achievements are an essential predictor of flow.

Furthermore, experience points (XP) can represent the player's skill level. In LetterLink, the amount of experience points indicates the number of valid words a player has placed. For instance, a player with many experience points is most likely skilled because the player must have played many games to get a high amount of points. On the other hand, experience points can also represent a challenge in the sense of obtaining the most amount of experience points. In LetterLink, the amount of experience points can be shown and compared in the leaderboard component. A possible explanation why experience points can predict the players' state of flow

could be in the way that experience points skill and balance facets ensures a perfect balance between skill and challenge which are essential for achieving flow.

The fact that sounds can increase the player's flow is supported by [15, 60]. Levy et al. [60] argue that sound improved the participants' ability to focus, made time seem to pass more quickly, and made the activity feel more gratifying. For that reason, it seems like including sounds in games is an essential factor in achieving flow. This also shows that for someone to be in the state of flow, a combination of cognitive, affective, motivational, and metacognitive factors is required [36]); thus, the state of flow (as well as engagement) cannot be measured or researched as a unidimensional construct, particularly, when we aim to understand the complex processes of learning and engagement as combinations of individual, interpersonal, and contextual factors related to human learning and engagement.

7.2 Game Design Elements Contribution to Engagement as a Multidimensional Construct

RQ2: *What specific game design elements in a serious game context contribute the most and the least to engagement as a multidimensional construct?*

The game design element that contributed the most to engagement as a multidimensional construct is **experience points** (XP), which was found to influence *flow*, *affective* (i.e., sensory and imaginative immersion), and *motivational* engagement (i.e., competence). It also seems like experience points have an effect on *behavioral* engagement. For that reason, experience points seem vital to include in the design of a serious game in order to increase the players' engagement in various dimensions.

Following, the **inclusion of game design elements in general** was found to affect the players' *positive* and *negative affect*. **Sound** influenced *affective engagement* (i.e., sensory and imaginative immersion) and affected the players' flow state. **Streaks** were also found to influence *affective engagement*.

The achievement influenced the player's flow state and is assumed to impact *behavioral engagement*. **Level** influenced *behavioral engagement* and was the only game design element to affect *cognitive engagement*. Therefore, levels are crucial to adapt to serious games to ensure cognitive engagement.

Both **profile statistics** and **leaderboard** failed to predict any of the GEQ's seven engagement factors, which might indicate they were less important to engage the player. However, it seems reasonable that the leaderboard impacted the increase in behavioral engagement. Previous research has found that the leaderboard is important in promoting user engagement [12, 13, 14, 15] by contributing to feelings of competitiveness. Considering the fact that both profile statistics and leaderboard shows the users' amount of experience points, a possible explanation is that these game design elements are not properly isolated from experience points, making the user pay less attention to the leaderboard and the profile statistics as separate game design elements.

Another explanation might be that the LetterLink game, as designed for learning vocabulary and training spelling, did not require nor spark competitiveness among the players as they intended to learn and engage in a learning experience and not have the need to win. This shows that serious games can be designed with the intention to learn and engage in a learning experience without the need to be competitive or aim to win more than the aim to learn and have a positive experience with peers.

Confetti animation failed to predict any engagement dimensions, which may indicate that it is not vital for the user's engagement in serious games.

Overall, the findings demonstrate that different game design elements affect various dimensions of engagement. For players to be engaged, a combination of cognitive, affective, motivational, and behavioral factors must be present. Including a leaderboard might affect the players' *behavior* and make them engage in more games and play longer. The inclusion of levels and *cognitive* challenges introduces a goal to reach for. The inclusion of experience points seems to evoke the players'

emotions by making them feel good about themselves and feel successful in what they are doing so that they are *motivated* to continue playing**.** The game should also make the player feel a certain level of tension so that they are willing to put some effort into overcoming the challenges, and to be in the flow zone [37]. All these factors capture different dimensions of engagement and point out that engagement cannot be measured or researched as a unidimensional construct. Further studies should coin engagement as a multidimensional construct that captures individual, interpersonal, and contextual factors related to human learning [36].

7.3 Gender, Gaming Frequency, and Age's Effect on Engagement

RQ3: *Are the potential benefits of game design elements in a serious game context limited to or enhanced in participants depending on external factors such as age, gender, and experience with playing games?*

7.3.1 Gender

There were **no significant differences** regarding gender, which are consistent with previous research [37, 38]. This indicates that the player's level of engagement seems to not be limited to the player's gender.

7.3.2 Gaming Frequency and Experience

Regarding the players' gaming frequency, **frequent players** (i.e., players who spend more than 2 hours playing games in general per week) experienced **more negative affect** in the **first week**, where no game design elements were present. This difference may arise because frequent players may have more gaming experience and therefore have greater expectations and standards for the game [135]. When game design elements are missing, the players may perceive the experience as shallow or without depth, resulting in disappointment, boredom, or irritation. In

contrast, non-frequent players may have lower expectations and approach the game with a more easygoing perspective, resulting in fewer negative emotions.

In addition, **frequent players** were involved in **more games** in the **second week** than non-frequent players, where game design elements were present. This difference may arise because frequent players have experience with other games; they might have a higher perceived level of skill compared to players who do not play games often. As a result, frequent players may be more likely than non-frequent players to have the time and motivation to play numerous games within a given timeframe. This is supported by Larche and Dixon [136], who states that players with high perceived skill experience more flow, making them more motivated to play.

Frequent players also had significantly **more games ending in a draw** in the **second week** than non-frequent players. Because frequent players have more experience with games in general, they may be more skilled in the game. Frequent players might better understand the rules, tactics, and optimal play, which could lead to more evenly balanced play and a higher probability of draws.

7.3.3 Age

When **no game design elements** are present, it is interesting to note that participants between the **age of 25 and 39** had significantly **more games** than the **oldest age group (40+)**. This disparity may show that factors other than game design elements contribute to the greater game count among people aged 25 to 39. People between the ages of 25 to 39 may be more comfortable with technology and more experienced with educational games, making them less likely to expect to be as engaged in a serious game as in an authentic video game [137]. This may increase their likelihood of accessing and exploring a greater choice of serious games.

When game design elements were introduced in the second week, the **middle-aged group (25-39)** had significantly **more opponents**, **higher total points,** and **lost more games** than the **youngest age group (15-24)**. The findings indicate that

people in their late twenties and thirties have particular features that allow them to succeed in gaming situations. Firstly, the number of opponents may imply that people aged 25 to 39 actively seek competitive challenges and are more likely to engage in multiplayer gaming. Second, the higher total points might indicate that the middle-aged group (25-39) has established a level of competency and knowledge in terms of their vocabulary, allowing them to attain greater scores and succeed in various game design elements. Finally, the greater frequency of losses could indicate that people between the ages of 25 and 39 are more willing to take risks, try new techniques, and learn from their mistakes in order to improve their gameplay.

In addition, the **oldest age group (40+)** had significantly **more experience points** than the **youngest age group (15-24)** in the second week. A possible explanation is that older people, due to their life experience, may have developed better strategic thinking and problem-solving skills, which may have contributed to their ability to choose words wisely [138], leading to a higher amount of experience points. In addition, older people may have had more exposure to gaming over the years, which may have contributed to a deeper comprehension of game dynamics and tactics.

Overall, the age-related findings contradict Koivisto and Hamari's [139] assertion that the advantages of gamification diminish with age. This may be because their research was conducted in a different setting (i.e., exergames) where age differences may express themselves differently.

7.4 Strengths and limitations

7.4.1 Strengths

The game design elements in LetterLink are grounded in different theories (Malone’s Theory of Enjoyment, the GameFlow Framework, the Game Reward System, the Gamification Taxonomy) and by analyzing related games. With this, we ensure the game design elements are relevant and implemented correctly.

As described in Section 3.6, LetterLink includes several different game design elements. This includes a streaks feature, which many games do not have. Furthermore, the application strongly focuses on performance and usability through server-side rendering, Mantine as a component library, and Firebase real-time data listeners. We believe LetterLink provides a pleasant and fun gameplay experience even without the game design elements. This is advantageous because we reduce the risk of players being frustrated by poor performance or user experience, affecting the questionnaire answers and behavioral data.

In this research project, engagement is thoroughly defined [18] and considered a multidimensional construct [39, 75]. This is advantageous because it provides clarity of understanding engagement as a complex concept and clarity in terms of what is being measured.

To answer the research questions, multiple analysis methods were conducted to increase the robustness of the results in this thesis. Each analysis method provides unique insights and perspectives on the data, allowing for a more holistic interpretation of the findings. When different methods consistently yield similar outcomes, it enhances confidence in our findings and reduces the potential for bias or chance effects.

7.4.2 Limitations

The game design element experience points were a part of both profile statistics, levels, and leaderboards. This might have affected the questionnaire results, where participants might have thought that questions regarding the experience points component also included profile statistics, levels, and leaderboards.

When using the Chrome browser application on iOS devices, users could not drag the letter to a grid slot on iOS devices. Those who experienced this error were told to use a different mobile browser or switch to playing on a desktop. Users might have felt frustrated and less engaged in the playing experience when encountering this error, affecting the questionnaire results.

After each week that participants were playing, they had one week to answer the questionnaire. Some participants waited several days, sometimes postponing answering until Sunday. This might have led them to forget how they felt during playing. Since GEQ is shown to have a forgiveness effect (i.e., players may forget or forgive an adverse event if it is followed by a time when they have a positive one) [112], this might have affected the questionnaire results. Ideally, participants would answer the questionnaire the Monday following the playing week, but it is unrealistic to expect this. We could have set a deadline for answering the questionnaire the following Wednesday, but we felt this would be intrusive, especially when participants were not rewarded for partaking.

Except for the game design elements, the game and gameplay were identical in both playing weeks. A disadvantage of choosing a repeated measure design is the risk of order effects [134]. For instance, players might have practiced in the first week, making them better at placing words that give points in the second week. In addition, the players might be tired of playing the game already in the first week, making them feel bored in the second week. Both situations could have affected the participants' motivation and engagement positively or negatively.

The application does not notify players when it is their turn to make a move, for instance, through a push notification or an email. This feature was highly prioritized during development. However, due to users in Firebase being anonymous, there was no way of notifying a user after a move. Players were required to open the app to see if the opponent had made a move. In cases where a player regularly checks, but no move has been made, it might make the player feel frustrated or irritated, affecting the questionnaire results. We foresaw this issue and, as a countermeasure, encouraged players to play and finish a game during one session, meaning players would take five minutes or so to start and complete a game. On the other hand, with participants being anonymous, it took much work for players to find others to play with.

7.5 Implications of Findings

Based on the findings, we propose the following guidelines for adding game design elements in a serious game, as can be seen in Table 7.1:

Table 7.1: *Guidelines for engaging users through the use of game design elements*

Engagement Dimension	Game design element found to increase the engagement dimension
Flow	Sound Experience points Achievements
Affective	Streaks Experience points Sound
Cognitive	Level
Motivational	Experience points
Behavioral	Achievement Experience points Levels Leaderboards

7.6 Future work

The findings of this thesis suggest that the inclusion of game design elements in LetterLink had a positive effect on the player's engagement. Therefore, looking further at the educational effect for vocabulary learning and retention that LetterLink can provide would be interesting. According to Perttula et al. [140], flow experience positively affects learning. Furthermore, Natucci and Borges [141] claim that there is a knowledge gap between certain game design elements and the effect they might have on learning. Researching this would add to the current knowledge of the relationship between game design elements and learning.

While serious games have been used for vocabulary acquisition and retention, few have implemented and tested input and output language skills in a digital game-based language learning context [142]. This is a possible use case for LetterLink.

Determining the effect notifications have on player retention and engagement would be interesting. However, one would need to figure out how to send notifications to users when everything on the server and in the database is anonymous.

Research with a control group would be valuable to verify our findings. In addition, it would be interesting to conduct regression analysis with the behavioral measurement as dependent variables to justify our assumptions on the specific game design elements' effect on behavioral engagement.

8 Conclusion

This research assessed the effects of game design elements on engagement as a multidimensional construct (including behavioral, affective, cognitive, and motivational dimensions) in a serious game for vocabulary learning and retention. The research was conducted using a design-based research approach. Participants first played the serious game without game design elements for a week, then with game design elements, counting an achievement system, leaderboard, streaks, experience points, and feedback components such as animations, sounds, level, and profile statistics. Self-report and log data were collected. Each measurement was mapped to one of the engagement dimensions to extend the understanding of user engagement as a multidimensional construct.

Overall, the results indicate that including game design elements in a serious game like LetterLink is critical to ensure user engagement. Our findings suggest that different game design elements significantly affect various engagement dimensions. Age, gaming frequency, streaks, experience points, and sound influence affective engagement. Levels were the only game design elements contributing to cognitive engagement, and experience points were the only element contributing to motivational engagement. Age and gaming frequency was found to predict behavioral engagement. In addition, it seems like the inclusion of achievements, experience points, levels, and leaderboards contributed to the increase in behavioral engagement. No gender differences were observed. Our results indicate that engagement must be considered a multidimensional construct, and we hope that these findings will inspire further research to coin engagement in the same way.

References

[1] M. Trinidad, M. Ruiz, and A. Calderon, “A Bibliometric Analysis of Gamification Research,” *IEEE Access*, vol. 9, pp. 46505–46544, 2021, doi: 10.1109/ACCESS.2021.3063986.

[2] A. A. A. Ahmed *et al.*, “Assessing the Effects of Gamification on Developing EFL Learners’ Idiomatic Knowledge: Do Attitudinal Factors Contribute to the Learning of the Idioms with the Game?,” *Educ. Res. Int.*, vol. 2022, pp. 1–10, Mar. 2022, doi: 10.1155/2022/2482570.

[3] O. A. Ochihu, “Effects of Gamification and Mastery Learning Strategies On Student’s Performance and Retention in Mathematics in Oju Local Government Area of Benue State,” *Br. J. Educ.*, vol. 10, no. 8, pp. 18–30, Jul. 2022, doi: 10.37745/bje.2013/vo10.n8pp1830.

[4] L. Szendrői, K. S. Dhir, and K. Czakó, “Implementing Gamified Teaching: Exploring the Effects of Gamification and Personal Types in an Economics Course,” *Int. J. Game-Based Learn.*, vol. 12, no. 1, pp. 1–19, Jan. 2022, doi: 10.4018/IJGBL.294014.

[5] C.-H. Hung and Y.-S. Kao, “Learning More About the Effects of Gamification on Physical Activity. Comment on ‘Evaluating the Effectiveness of Gamification on Physical Activity: Systematic Review and Meta-analysis of Randomized Controlled Trials,’” *J. Med. Internet Res.*, vol. 24, no. 5, p. e36396, May 2022, doi: 10.2196/36396.

[6] K. Larson, “Serious Games and Gamification in the Corporate Training Environment: a Literature Review,” *TechTrends*, vol. 64, no. 2, pp. 319–328, Mar. 2020, doi: 10.1007/s11528-019-00446-7.

[7] S. Carlier, D. Coppens, F. De Backere, and F. De Turck, “Investigating the Influence of Personalised Gamification on Mobile Survey User Experience,” *Sustainability*, vol. 13, no. 18, p. 10434, Sep. 2021, doi: 10.3390/su131810434.

[8] University of Cebu-Lapu-Lapu and Mandaue A.C. Cortes Ave., Looc, Mandaue City, Cebu, Philippines, E. B. Sabornido, V. A. Garma, G. L. Niepes, and F. M. N. Cabria, “Key Challenges and Barriers in Gamification: A Systematic Review,” *APJAET - J. Ay Asia Pac. J. Adv. Educ. Technol.*, vol. 1, no. 1, pp. 13–19, Mar. 2022, doi: 10.54476/apjaetv1i1mar20221054.

[9] R. C. Callan, K. N. Bauer, and R. N. Landers, “How to Avoid the Dark Side of Gamification: Ten Business Scenarios and Their Unintended Consequences,” T. Reiners and L. C. Wood, Eds., Cham: Springer International Publishing, 2015, pp. 553–568. doi: 10.1007/978-3-319-10208-5_28.

[10] S. Barragán-Pulido, M. L. Barragán-Pulido, J. B. Alonso-Hernández, J. J. Castro-Sánchez, and M. J. Rabazo-Méndez, “Development of Students’ Skills through Gamification and Serious Games: An Exploratory Study,” *Appl. Sci.*, vol. 13, no. 9, Art. no. 9, Jan. 2023, doi: 10.3390/app13095495.

[11] A. Yazdi and J. Hatami, “Review of Articles in the Field of Effects and Factors Affecting Gamification: Review of Articles in the Field of Effects and Factors Affecting Gamification,” *Int. J. Learn. Spaces Stud.*, vol. 1, no. 2, Art. no. 2, Apr. 2023.

[12] C. Groening and C. Binnewies, “The More, the Merrier? - How Adding and Removing Game Design Elements Impact Motivation and Performance in a Gamification Environment,” *Int. J. Human–Computer Interact.*, vol. 37, no. 12,

pp. 1130–1150, Jul. 2021, doi: 10.1080/10447318.2020.1870828.
[13] D. Kao and D. F. Harrell, “The Effects of Badges and Avatar Identification on Play and Making in Educational Games,” *Proc. 2018 CHI Conf. Hum. Factors Comput. Syst.*, pp. 1–19, Apr. 2018, doi: 10.1145/3173574.3174174.
[14] K. Kiili, “Designing Educational Games: Integrating Game Design Principles in Learning Contexts.,” Dec. 2005.
[15] L. E. Nacke, M. N. Grimshaw, and C. A. Lindley, “More than a feeling: Measurement of sonic user experience and psychophysiology in a first-person shooter game,” *Interact. Comput.*, vol. 22, no. 5, pp. 336–343, Sep. 2010, doi: 10.1016/j.intcom.2010.04.005.
[16] L. Amo, R. Liao, R. Kishore, and H. R. Rao, “Effects of structural and trait competitiveness stimulated by points and leaderboards on user engagement and performance growth: A natural experiment with gamification in an informal learning environment,” *Eur. J. Inf. Syst.*, vol. 29, no. 6, pp. 704–730, Nov. 2020, doi: 10.1080/0960085X.2020.1808540.
[17] S. Bai, K. F. Hew, M. Sailer, and C. Jia, “From top to bottom: How positions on different types of leaderboard may affect fully online student learning performance, intrinsic motivation, and course engagement,” *Comput. Educ.*, vol. 173, p. 104297, Nov. 2021, doi: 10.1016/j.compedu.2021.104297.
[18] G. Hookham and K. Nesbitt, “A Systematic Review of the Definition and Measurement of Engagement in Serious Games,” in *Proceedings of the Australasian Computer Science Week Multiconference*, Sydney NSW Australia: ACM, Jan. 2019, pp. 1–10. doi: 10.1145/3290688.3290747.
[19] O. Bernardes, V. Amorim, and A. C. Moreira, *Handbook of Research on Gamification Dynamics and User Experience Design*. IGI Global, 2022. Accessed: Apr. 26, 2023. [Online]. Available: https://doi.org/10.4018/978-1-6684-4291-3
[20] A. Suh, C. Wagner, and L. Liu, “The Effects of Game Dynamics on User Engagement in Gamified Systems,” in *2015 48th Hawaii International Conference on System Sciences*, Jan. 2015, pp. 672–681. doi: 10.1109/HICSS.2015.87.
[21] A. Suh, C. Wagner, and L. Liu, “Enhancing User Engagement through Gamification,” *J. Comput. Inf. Syst.*, vol. 58, no. 3, pp. 204–213, Jul. 2018, doi: 10.1080/08874417.2016.1229143.
[22] L. Stege, G. van Lankveld, P. Spronck, and P. O. Box, “Serious Games in Education,” *Int. J. Comput. Sci. Sport*, vol. 10.
[23] R. Ferdig and B. Winn, “The Design, Play, and Experience Framework,” 2009, pp. 1010–1024. doi: 10.4018/978-1-59904-808-6.ch058.
[24] Y. Zhonggen, “A Meta-Analysis of Use of Serious Games in Education over a Decade,” *Int. J. Comput. Games Technol.*, vol. 2019, pp. 1–8, Feb. 2019, doi: 10.1155/2019/4797032.
[25] Kim, Sa-Hoon H., “A Research on the Extended Definition of Educational Serious Game and Guiding Directions through Categorizations of Serious Games,” in *Journal of Korea Game Society*, Feb. 2012, pp. 3–13. doi: 10.7583/JKGS.2012.12.1.3.
[26] D. Mariaca, D. Guzman, and J. Londono, “A serious game for cognitive and fine motor skill rehabilitation: a qualitative evaluation,” *2022 IEEE 40th Cent. Am. Panama Conv. CONCAPAN*, pp. 1–6, Nov. 2022, doi: 10.1109/CONCAPAN48024.2022.9997622.

[27] L. Panagiotopoulou *et al.*, “Design of a Serious Game for Children to Raise Awareness on Plastic Pollution and Promoting Pro-Environmental Behaviors,” *J. Comput. Inf. Sci. Eng.*, vol. 21, no. 6, p. 064502, Dec. 2021, doi: 10.1115/1.4050291.
[28] G. Romagnoli, M. Galli, D. Mezzogori, and D. Reverberi, “Cooperative and Competitive Serious Game for Operations and Supply Chain Management: Didactical Concept and Final Evaluation,” *Int. J. Online Biomed. Eng. IJOE*, vol. 18, no. 15, pp. 17–30, Dec. 2022, doi: 10.3991/ijoe.v18i15.35089.
[29] L. Elaachak, A. Belahbibe, and M. Bouhorma, “Towards a System of Guidance, Assistance and Learning Analytics Based on Multi Agent System Applied on Serious Games,” *Int. J. Electr. Comput. Eng. IJECE*, vol. 5, no. 2, p. 344, Apr. 2015, doi: 10.11591/ijece.v5i2.pp344-354.
[30] K. Khowaja and S. S. Salim, “A framework to design vocabulary-based serious games for children with autism spectrum disorder (ASD),” *Univers. Access Inf. Soc.*, vol. 19, no. 4, pp. 739–781, Nov. 2020, doi: 10.1007/s10209-019-00689-4.
[31] N. Dinçer and R. Dinçer, “effect of a serious game on aviation vocabulary acquisition,” *Int. J. Serious Games*, vol. 8, no. 4, pp. 49–63, Dec. 2021, doi: 10.17083/ijsg.v8i4.464.
[32] N. Kara, “The Effect of Serious Mobile Games on Student English Vocabulary Acquisition and Attitude Toward English:,” *Int. J. Comput.-Assist. Lang. Learn. Teach.*, vol. 12, no. 1, pp. 1–16, Mar. 2022, doi: 10.4018/IJCALLT.297203.
[33] V. P. Roslin and M. Hosseinpour Emam, “Investigating the Effect of Serious Games as an Intervention on Iranian EFL Learners’ Vocabulary Learning and Retention during COVID-19 Pandemic,” *SRPH J. Interdiscip. Stud.*, Oct. 2021, doi: 10.47176/sjis.3.2.1.
[34] T. W. Malone, “What Makes Things Fun to Learn? A Study of Intrinsically Motivating Computer Games,” *Pipeline*, vol. 6, Jan. 1981.
[35] P. Sweetser and P. Wyeth, “GameFlow: A Model for Evaluating Player Enjoyment in Games,” *ACM Comput. Entertain.*, vol. 3, no. 3, p. 24, Jul. 2005.
[36] R. Azevedo, “Defining and Measuring Engagement and Learning in Science: Conceptual, Theoretical, Methodological, and Analytical Issues,” *Educ. Psychol.*, vol. 50, no. 1, pp. 84–94, Jan. 2015, doi: 10.1080/00461520.2015.1004069.
[37] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*. New York, NY, USA: Harper & Row, 1990.
[38] J. Chumbley and M. Griffiths, “Affect and the Computer Game Player: The Effect of Gender, Personality, and Game Reinforcement Structure on Affective Responses to Computer Game-Play,” *Cyberpsychol. Behav.*, vol. 9, no. 3, pp. 308–316, Jun. 2006, doi: 10.1089/cpb.2006.9.308.
[39] G. M. Sinatra, B. C. Heddy, and D. Lombardi, “The Challenges of Defining and Measuring Student Engagement in Science,” *Educ. Psychol.*, vol. 50, no. 1, pp. 1–13, Jan. 2015, doi: 10.1080/00461520.2014.1002924.
[40] E. L. Deci and R. M. Ryan, “The ‘What’ and ‘Why’ of Goal Pursuits: Human Needs and the Self-Determination of Behavior,” *Psychol. Inq.*, vol. 11, no. 4, pp. 227–268, Oct. 2000, doi: 10.1207/S15327965PLI1104_01.
[41] H. Wang and C.-T. Sun, “Game Reward Systems: Gaming Experiences and Social Meanings,” p. 15, 2011.
[42] A. M. Toda *et al.*, “Analysing gamification elements in educational

environments using an existing Gamification taxonomy," *Smart Learn. Environ.*, vol. 6, no. 1, p. 16, Dec. 2019, doi: 10.1186/s40561-019-0106-1.
[43] A. Kankanhalli, M. Taher, H. Cavusoglu, and S. H. Kim, "Gamification: A New Paradigm for Online User Engagement," 2012.
[44] J. L. D. Neys, J. Jansz, and E. S. H. Tan, "Exploring persistence in gaming: The role of self-determination and social identity," *Comput. Hum. Behav.*, vol. 37, pp. 196–209, Aug. 2014, doi: 10.1016/j.chb.2014.04.047.
[45] F. Guay, R. J. Vallerand, and C. Blanchard, "On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS)," *Motiv. Emot.*, vol. 24, no. 3, pp. 175–213, Sep. 2000, doi: 10.1023/A:1005614228250.
[46] R. M. Ryan, C. S. Rigby, and A. Przybylski, "The Motivational Pull of Video Games: A Self-Determination Theory Approach," *Motiv. Emot.*, vol. 30, no. 4, pp. 344–360, Dec. 2006, doi: 10.1007/s11031-006-9051-8.
[47] C. Phillips, D. Johnson, M. Klarkowski, M. J. White, and L. Hides, "The Impact of Rewards and Trait Reward Responsiveness on Player Motivation," in *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, Melbourne VIC Australia: ACM, Oct. 2018, pp. 393–404. doi: 10.1145/3242671.3242713.
[48] J. Koivisto and J. Hamari, "The rise of motivational information systems: A review of gamification research," *Int. J. Inf. Manag.*, vol. 45, pp. 191–210, Apr. 2019, doi: 10.1016/j.ijinfomgt.2018.10.013.
[49] O. Pedreira, F. García, N. Brisaboa, and M. Piattini, "Gamification in software engineering – A systematic mapping," *Inf. Softw. Technol.*, vol. 57, pp. 157–168, Jan. 2015, doi: 10.1016/j.infsof.2014.08.007.
[50] K. Seaborn and D. I. Fels, "Gamification in theory and action: A survey," *Int. J. Hum.-Comput. Stud.*, vol. 74, pp. 14–31, Feb. 2015, doi: 10.1016/j.ijhcs.2014.09.006.
[51] A. M. Toda *et al.*, "A Taxonomy of Game Elements for Gamification in Educational Contexts: Proposal and Evaluation," in *2019 IEEE 19th International Conference on Advanced Learning Technologies (ICALT)*, Jul. 2019, pp. 84–88. doi: 10.1109/ICALT.2019.00028.
[52] A. Dignan, *Game Frame: Using Games as a Strategy for Success*. Simon and Schuster, 2011.
[53] P. M. Papadopoulos, T. Lagkas, and S. N. Demetriadis, "How Revealing Rankings Affects Student Attitude and Performance in a Peer Review Learning Environment," in *Computer Supported Education*, S. Zvacek, M. T. Restivo, J. Uhomoibhi, and M. Helfert, Eds., in Communications in Computer and Information Science. Cham: Springer International Publishing, 2016, pp. 225–240. doi: 10.1007/978-3-319-29585-5_13.
[54] A. M. Toda, R. M. C. do Carmo, A. P. da Silva, I. I. Bittencourt, and S. Isotani, "An approach for planning and deploying gamification concepts with social networks within educational contexts," *Int. J. Inf. Manag.*, vol. 46, pp. 294–303, Jun. 2019, doi: 10.1016/j.ijinfomgt.2018.10.001.
[55] K. Larssen and A. Amundsen, "Measuring Engagement In Serious Games (Preparatory Project)." 2022.
[56] D. Badampudi, C. Wohlin, and K. Petersen, "Experiences from using snowballing and database searches in systematic literature studies," in *Proceedings of the 19th International Conference on Evaluation and*

Assessment in Software Engineering, Nanjing China: ACM, Apr. 2015, pp. 1–10. doi: 10.1145/2745802.2745818.

[57] C. Wohlin, “Guidelines for snowballing in systematic literature studies and a replication in software engineering,” in *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, London England United Kingdom: ACM, May 2014, pp. 1–10. doi: 10.1145/2601248.2601268.

[58] C. Klimmt, T. Hartmann, and A. Frey, “Effectance and Control as Determinants of Video Game Enjoyment,” *Cyberpsychol. Behav.*, vol. 10, no. 6, pp. 845–848, Dec. 2007, doi: 10.1089/cpb.2007.9942.

[59] J. C. Chou, C. Hung, and Y. Hung, “Design factors of mobile game for increasing gamer’s flow experience,” *2014 IEEE Int. Conf. Manag. Innov. Technol.*, pp. 137–139, Sep. 2014, doi: 10.1109/ICMIT.2014.6942414.

[60] L. Levy, R. Solomon, M. Gandy, and R. Catrambone, “The Rhythm’s Going to Get You: Music’s Effects on Gameplay and Experience,” *Proc. 2015 Annu. Symp. Comput.-Hum. Interact. Play*, pp. 607–612, Oct. 2015, doi: 10.1145/2793107.2810329.

[61] D. Weibel, B. Wissmath, S. Habegger, Y. Steiner, and R. Groner, “Playing online games against computer- vs. human-controlled opponents: Effects on presence, flow, and enjoyment,” *Comput. Hum. Behav.*, vol. 24, no. 5, pp. 2274–2291, Sep. 2008, doi: 10.1016/j.chb.2007.11.002.

[62] M. Sailer, J. U. Hense, S. K. Mayr, and H. Mandl, “How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction,” *Comput. Hum. Behav.*, vol. 69, pp. 371–380, Apr. 2017, doi: 10.1016/j.chb.2016.12.033.

[63] E. McAuley, T. Duncan, and V. V. Tammen, “Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: a confirmatory factor analysis,” *Res. Q. Exerc. Sport*, vol. 60, no. 1, pp. 48–58, Mar. 1989, doi: 10.1080/02701367.1989.10607413.

[64] M. M. Handelsman, W. L. Briggs, N. Sullivan, and A. Towler, “A Measure of College Student Course Engagement,” *J. Educ. Res.*, vol. 98, no. 3, pp. 184–192, Jan. 2005, doi: 10.3200/JOER.98.3.184-192.

[65] J. T. Bowey, M. V. Birk, and R. L. Mandryk, “Manipulating Leaderboards to Induce Player Experience,” *Proc. 2015 Annu. Symp. Comput.-Hum. Interact. Play*, pp. 115–120, Oct. 2015, doi: 10.1145/2793107.2793138.

[66] B. Fritz and A. Avsec, “The experience of flow and subjective well-being of music students,” Jul. 2007.

[67] I. J. Lewis, A. Zulkifly, and K. Salas, “The effects of videogame achievements on player motivation,” presented at the International Conference on Computer and Information Technology, 2015.

[68] P. Denny, “The effect of virtual achievements on student engagement,” *Proc. SIGCHI Conf. Hum. Factors Comput. Syst.*, pp. 763–772, Apr. 2013, doi: 10.1145/2470654.2470763.

[69] J. A. Fredricks, “Engagement in School and Out-of-School Contexts: A Multidimensional View of Engagement,” *Theory Pract.*, vol. 50, no. 4, pp. 327–335, Oct. 2011, doi: 10.1080/00405841.2011.607401.

[70] B. L. Fredrickson and C. Branigan, “Positive emotions broaden the scope of attention and thought-action repertoires,” *Cogn. Emot.*, vol. 19, no. 3, pp. 313–332, May 2005, doi: 10.1080/02699930441000238.

[71] H. Schoenau-Fog, “The Player Engagement Process – An Exploration of Continuation Desire in Digital Games,” vol. 6, Jan. 2011.
[72] E. Brown and P. Cairns, “A grounded investigation of game immersion,” in *CHI ’04 Extended Abstracts on Human Factors in Computing Systems*, Vienna Austria: ACM, Apr. 2004, pp. 1297–1300. doi: 10.1145/985921.986048.
[73] A. C. Y. Hou, C.-C. Chern, H.-G. Chen, and Y.-C. Chen, “‘Migrating to a new virtual world’: Exploring MMORPG switching through human migration theory,” *Comput. Hum. Behav.*, vol. 27, no. 5, pp. 1892–1903, Sep. 2011, doi: 10.1016/j.chb.2011.04.013.
[74] B. Mansouri, A. Roozkhosh, and H. Farbeh, “A Survey on Implementations of Adaptive AI in Serious Games for Enhancing Player Engagement,” in *2021 International Serious Games Symposium (ISGS)*, Nov. 2021, pp. 48–53. doi: 10.1109/ISGS54702.2021.9684760.
[75] C. Mills, S. D’Mello, B. Lehman, N. Bosch, A. Strain, and A. Graesser, “What Makes Learning Fun? Exploring the Influence of Choice and Difficulty on Mind Wandering and Engagement during Learning,” in *Artificial Intelligence in Education*, H. C. Lane, K. Yacef, J. Mostow, and P. Pavlik, Eds., in Lecture Notes in Computer Science. Berlin, Heidelberg: Springer, 2013, pp. 71–80. doi: 10.1007/978-3-642-39112-5_8.
[76] R. Pekrun, *International Handbook of Emotions in Education*. New York: Routledge, 2014. doi: 10.4324/9780203148211.
[77] A. Wigfield and J. S. Eccles, “Expectancy–Value Theory of Achievement Motivation,” *Contemp. Educ. Psychol.*, vol. 25, no. 1, pp. 68–81, Jan. 2000, doi: 10.1006/ceps.1999.1015.
[78] S. L. Christenson, A. L. Reschly, and C. Wylie, *Handbook of Student Engagement*. 2012.
[79] W. A. IJsselsteijn, Y. A. W. de Kort, and K. Poels, *The Game Experience Questionnaire*. Eindhoven: Technische Universiteit Eindhoven, 2013.
[80] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, “From game design elements to gamefulness: defining ‘gamification,’” in *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, in MindTrek ’11. New York, NY, USA: Association for Computing Machinery, Sep. 2011, pp. 9–15. doi: 10.1145/2181037.2181040.
[81] S. Deterding, M. Sicart, L. Nacke, K. O’Hara, and D. Dixon, “Gamification. using game-design elements in non-gaming contexts,” in *CHI ’11 Extended Abstracts on Human Factors in Computing Systems*, in CHI EA ’11. New York, NY, USA: Association for Computing Machinery, May 2011, pp. 2425–2428. doi: 10.1145/1979742.1979575.
[82] J. Hamari, J. Koivisto, and H. Sarsa, “Does Gamification Work? – A Literature Review of Empirical Studies on Gamification,” in *2014 47th Hawaii International Conference on System Sciences*, Jan. 2014, pp. 3025–3034. doi: 10.1109/HICSS.2014.377.
[83] S. Chairani, “Using Scrabble For Learning English Vocabulary At Man 2 Kuantan Singingi,” *Lang. Lit. J. Linguist. Lit. Lang. Teach.*, vol. 5, no. 1, pp. 205–212, Jun. 2021, doi: 10.30743/ll.v5i1.3858.
[84] K. Suwanviwatana and H. Iida, “First Results from Using Game Refinement Measure and Learning Coefficient in Scrabble.” arXiv, Nov. 07, 2017. doi: 10.48550/arXiv.1711.03580.
[85] W. Widiawati, “The Implementation Of Scrabble Board Game To Teach

Vocabulary At The Eleventh Grade Students Of Muhammadiyah Senior High School 3 Batu," Jul. 2016.
[86] "Creative Words Text Free Stock Photo," *rawpixel*. https://www.rawpixel.com/image/5915776/image-public-domain-wood-letters (accessed May 26, 2023).
[87] "Wordfeud - multiplayer word game for iOS and Android." https://wordfeud.com/ (accessed Nov. 14, 2022).
[88] "Wordfeud - Apps on Google Play." https://play.google.com/store/apps/details?id=com.hbwares.wordfeud.free&hl=en_US&gl=US (accessed Dec. 01, 2022).
[89] "Wordle - A daily word game." https://www.nytimes.com/games/wordle (accessed Nov. 14, 2022).
[90] "WordPlus - Unique Word Game," *App Store*. https://apps.apple.com/us/app/wordplus-unique-word-game/id1642558385 (accessed Nov. 14, 2022).
[91] "Play Scrabble Online For Free | Play Scrabble," *Scrabble*. https://playscrabble.com/ (accessed May 11, 2023).
[92] P. Munday, "The Case For Using Duolingo As Part Of The Language Classroom Experience. Ried," in *RIED. Revista Iberoamericana de Educación a Distancia*, Sep. 2015. doi: 10.5944/ried.19.1.14581.
[93] K. Bicknell, C. Brust, and B. Settles, "How Duolingo's AI Learns what you Need to Learn: The language-learning app tries to emulate a great human tutor," *IEEE Spectr.*, vol. 60, no. 3, pp. 28–33, Mar. 2023, doi: 10.1109/MSPEC.2023.10061631.
[94] S. N. Amin, "Gamification Of Duolingo In Rising Student's English Language Learning Motivation," *J. Bhs. Lingua Sci.*, vol. 13, no. 2, pp. 191–213, Nov. 2021, doi: 10.21274/ls.2021.13.2.191-213.
[95] N. Nadiawati, "Gamification of Duolingo in Rising Childrens' second language learning motivation," Jul. 2018.
[96] "Duolingo - Language Lessons," *App Store*, May 22, 2023. https://apps.apple.com/us/app/duolingo-language-lessons/id570060128 (accessed May 26, 2023).
[97] M. Hassenzahl, "User experience (UX): Towards an experiential perspective on product quality," presented at the ACM International Conference Proceeding Series, Sep. 2008, pp. 11–15. doi: 10.1145/1512714.1512717.
[98] A. Amundsen and K. Larssen, "amunds1/LetterLink." Jan. 18, 2023. Accessed: Feb. 28, 2023. [Online]. Available: https://github.com/amunds1/LetterLink
[99] D. Norman, *The Design Of Everyday Things*, Revised edition. New York, New York: Basic Books, 2013.
[100] H. Kniberg, *Scrum and XP from the Trenches - 2nd Edition*. Lulu.com, 2015.
[101] N. Jain and S. Dubey, "Agile Development Methodology with cloud computing," 2014.
[102] V. A. Zanalda, "The Hybrid Application of Agile Project Management in IT Banking System: Optimization of Traditional Framework," Apr. 2019.
[103] J. Amann, O. Gasser, Q. Scheitle, L. Brent, G. Carle, and R. Holz, "Mission accomplished?: HTTPS security after diginotar," *Proc. 2017 Internet Meas. Conf.*, pp. 325–340, Nov. 2017, doi: 10.1145/3131365.3131401.
[104] F. Wang and M. J. Hannafin, "Design-based research and technology-enhanced learning environments," *Educ. Technol. Res. Dev.*, vol.

53, no. 4, pp. 5–23, Dec. 2005, doi: 10.1007/BF02504682.
[105] A. L. Brown, “Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings,” *J. Learn. Sci.*, vol. 2, no. 2, pp. 141–178, 1992.
[106] A. F. Wise and D. W. Shaffer, “Why Theory Matters More than Ever in the Age of Big Data,” *J. Learn. Anal.*, vol. 2, no. 2, Art. no. 2, Dec. 2015, doi: 10.18608/jla.2015.22.2.
[107] D. Collective, “Design-Based Research: An Emerging Paradigm for Educational Inquiry,” *Educ. Res.*, vol. 32, no. 1, pp. 5–8, Jan. 2003, doi: 10.3102/0013189X032001005.
[108] T. Anderson and J. Shattuck, “Design-Based Research: A Decade of Progress in Education Research?,” *Educ. Res.*, vol. 41, no. 1, pp. 16–25, Jan. 2012, doi: 10.3102/0013189X11428813.
[109] Ç. Aker, Y. Inal, and K. Rızvanoğlu, “A multi-modal approach for evaluating player experience on different gaming platforms,” *Int. J. Mob. Commun.*, vol. 18, no. 2, pp. 175–195, Jan. 2020, doi: 10.1504/IJMC.2020.105845.
[110] E. L.-C. Law, F. Brühlmann, and E. D. Mekler, “Systematic Review and Validation of the Game Experience Questionnaire (GEQ) - Implications for Citation and Reporting Practice,” in *Proceedings of the 2018 Annual Symposium on Computer-Human Interaction in Play*, in CHI PLAY ’18. New York, NY, USA: Association for Computing Machinery, Oct. 2018, pp. 257–270. doi: 10.1145/3242671.3242683.
[111] K. Oksanen, “Subjective Experience and Sociability in a Collaborative Serious Game,” *Simul. Gaming*, vol. 44, no. 6, pp. 767–793, Dec. 2013, doi: 10.1177/1046878113513079.
[112] S. S. Sabet, C. Griwodz, and S. Möller, “Influence of primacy, recency and peak effects on the game experience questionnaire,” in *Proceedings of the 11th ACM Workshop on Immersive Mixed and Virtual Environment Systems*, Amherst Massachusetts: ACM, Jun. 2019, pp. 22–27. doi: 10.1145/3304113.3326113.
[113] J. R. Chapman and P. J. Rich, “Does educational gamification improve students’ motivation? If so, which game elements work best?,” *J. Educ. Bus.*, vol. 93, no. 7, pp. 315–322, Oct. 2018, doi: 10.1080/08832323.2018.1490687.
[114] P. Chokrasamesiri and T. Senivongse, “User Engagement Analytics Based on Web Contents,” in *Computer and Information Science*, R. Lee, Ed., in Studies in Computational Intelligence. Cham: Springer International Publishing, 2016, pp. 73–87. doi: 10.1007/978-3-319-40171-3_6.
[115] N.-L. Hsueh, B. Daramsenge, and L.-C. Lai, “Exploring the Influence of Students’ Modes of Behavioral Engagement in an Online Programming Course Using the Partial Least Squares Structural Equation Modeling Approach,” *J. Inf. Technol. Educ. Res.*, vol. 21, pp. 403–423, 2022, doi: 10.28945/5010.
[116] S. D’Mello and A. Graesser, “Dynamics of affective states during complex learning,” *Learn. Instr.*, vol. 22, no. 2, pp. 145–157, Apr. 2012, doi: 10.1016/j.learninstruc.2011.10.001.
[117] J. P. Steele and C. J. Fullagar, “Facilitators and Outcomes of Student Engagement in a College Setting,” *J. Psychol.*, vol. 143, no. 1, pp. 5–27, Jan. 2009, doi: 10.3200/JRLP.143.1.5-27.
[118] S. D’Mello, E. Dieterle, and A. Duckworth, “Advanced, Analytic, Automated (AAA) Measurement of Engagement During Learning,” *Educ. Psychol.*, vol. 52,

no. 2, pp. 104–123, Apr. 2017, doi: 10.1080/00461520.2017.1281747.
[119] A. Ben-Eliyahu, D. Moore, R. Dorph, and C. D. Schunn, “Investigating the multidimensionality of engagement: Affective, behavioral, and cognitive engagement across science activities and contexts,” *Contemp. Educ. Psychol.*, vol. 53, pp. 87–105, Apr. 2018, doi: 10.1016/j.cedpsych.2018.01.002.
[120] J. A. Bopp, “Aesthetic Emotions in Digital Games: The Appeal of Moving, Challenging, and Thought-Provoking Player Experiences,” 2020.
[121] E. L. Deci, “Notes on the theory and metatheory of intrinsic motivation,” *Organ. Behav. Hum. Perform.*, vol. 15, no. 1, pp. 130–145, Feb. 1976, doi: 10.1016/0030-5073(76)90033-7.
[122] W. IJsselsteijn, Y. de Kort, and K. Poels, “Characterising and Measuring User Experiences in Digital Games,” p. 5, 2007.
[123] University in Oslo, “Nettskjema.” https://nettskjema.no/
[124] A. P. Field, *Discovering statistics using SPSS: and sex, drugs and rock “n” roll*, 3rd ed. Los Angeles: SAGE Publications, 2009.
[125] P. Kline, *Handbook of Psychological Testing*, 2nd ed. London: Routledge, 2000. doi: 10.4324/9781315812274.
[126] X. Li, “A simulation evaluation of backward elimination and stepwise variable selection in regression analysis,” 2012.
[127] A. Yehia, M. Saleh, and A.-H. Ahmed, “An Adjusted Correlation Coefficient for Canonical Correlation Analysis.,” *J. Egypt. Stat. Soc.*, Apr. 2016.
[128] T. Z. Keith, *Multiple regression and beyond: an introduction to multiple regression and structural equation modeling*, 2nd edition. New York ; London: Routledge, Taylor & Francis Group, 2015.
[129] J. V. Bittner and J. Shipper, “Motivational effects and age differences of gamification in product advertising,” *J. Consum. Mark.*, vol. 31, no. 5, pp. 391–400, Jan. 2014, doi: 10.1108/JCM-04-2014-0945.
[130] C. Heeter, Y.-H. Lee, B. Magerko, and B. Medler, “Impacts of Forced Serious Game Play on Vulnerable Subgroups:,” *Int. J. Gaming Comput.-Mediat. Simul.*, vol. 3, no. 3, pp. 34–53, Jul. 2011, doi: 10.4018/jgcms.2011070103.
[131] N. Gallacher, “Game audio — an investigation into the effect of audio on player immersion,” *Comput. Games J.*, vol. 2, no. 2, pp. 52–79, Aug. 2013, doi: 10.1007/BF03392342.
[132] S. Gormanley, “Audio immersion in games — a case study using an online game with background music and sound effects,” *Comput. Games J.*, vol. 2, no. 2, pp. 103–124, Aug. 2013, doi: 10.1007/BF03392344.
[133] G. Guillen, H. Jylhä, and L. Hassan, “The Role Sound Plays in Games:: A Thematic Literature Study on Immersion, Inclusivity and Accessibility in Game Sound Research,” *Acad. Mindtrek 2021*, pp. 12–20, Jun. 2021, doi: 10.1145/3464327.3464365.
[134] J. P. Verma, *Repeated Measures Design for Empirical Researchers*. John Wiley & Sons, 2015.
[135] J. Michalco, J. G. Simonsen, and K. Hornbæk, “An Exploration of the Relation Between Expectations and User Experience,” *Int. J. Human–Computer Interact.*, vol. 31, no. 9, pp. 603–617, Sep. 2015, doi: 10.1080/10447318.2015.1065696.
[136] C. J. Larche and M. J. Dixon, “The relationship between the skill-challenge balance, game expertise, flow and the urge to keep playing complex mobile games,” *J. Behav. Addict.*, vol. 9, no. 3, pp. 606–616, Oct. 2020, doi:

10.1556/jba-9-606.
[137] M. Sillaots, T. Jesmin, M. Fiadotau, and M. Khulbe, *Gamifying Classroom Presentations: Evaluating the Effects on Engagement Across Demographic Factors*. 2020.
[138] E. Kubina, N. Stepanova, Y. Davy, and L. Kondratyeva, “Universal Strategy Game,” in *European Conference on Games Based Learning*, Reading, United Kingdom: Academic Conferences International Limited, Sep. 2020, pp. 323-330,XV,XIX. doi: 10.34190/GBL.20.086.
[139] J. Koivisto and J. Hamari, “Demographic differences in perceived benefits from gamification,” *Comput. Hum. Behav.*, vol. 35, pp. 179–188, Jun. 2014, doi: 10.1016/j.chb.2014.03.007.
[140] A. Perttula, K. Kiili, A. Lindstedt, and P. Tuomi, “Flow experience in game based learning – a systematic literature review,” *Int. J. Serious Games*, vol. 4, no. 1, Art. no. 1, Mar. 2017, doi: 10.17083/ijsg.v4i1.151.
[141] G. C. Natucci and M. A. F. Borges, “Balancing Pedagogy, Emotions and Game Design in Serious Game Development,” in *Anais Estendidos do XX Simpósio Brasileiro de Jogos e Entretenimento Digital (SBGames Estendido 2021)*, Brasil: Sociedade Brasileira de Computação, Oct. 2021, pp. 1013–1016. doi: 10.5753/sbgames_estendido.2021.19749.
[142] T. Govender and J. Arnedo-Moreno, “An Analysis of Game Design Elements Used in Digital Game-Based Language Learning,” *Sustainability*, vol. 13, no. 12, p. 6679, Jun. 2021, doi: 10.3390/su13126679.

Appendices

Appendix A - Multiplayer Wordle task description

Multiplayer Wordle

Description

Multiplayer wordle is a two (or more) player wordle-like strategy game. The player can play against other players on the network or against the AI.

Rules of the game

Each player has their 5x5 matrix hidden from other players, which should be filled with letters. The object of the game is to form as many as possible three, four or five letters words. The game starts when one player chooses the letter and makes it visible to another player. Both players are required to choose the place for the letter in their matrix. Then, players interchangeably define letters that another player must also use. The game ends after 25 rounds when both matrices are filled with letters.

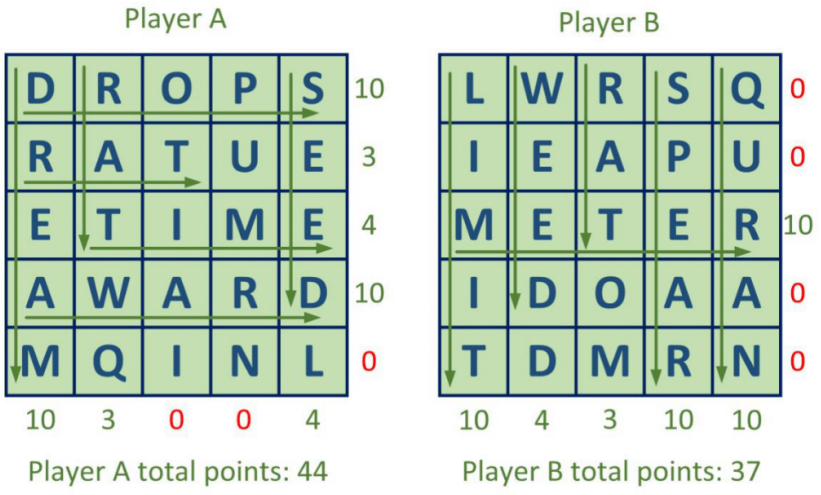
Calculating results

The winner is the player who earned more points after the following calculation:

- Five-letter word is worth 10 points
- Four-letter word is worth 4 points
- Three-letter word is worth 3 points

Words can be formed both vertically (from top to bottom) and horizontally (from left to right).

Example of results' calculation:



Notice that both matrices must contain the same letters.

Other variations of the game

Possible extensions of the game:

- Offer games for more than two players, where players choose letters one by one, and all other players are required to put the defined letters in their matrix.
- The matrix can be extended to 6x6, 7x7, etc.
- Different gradings of the words can be used.

Appendix B - Information letter

Vil du delta i forskningsprosjektet

LetterLink – Effekten av spilldesign-elementer

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å se på effekten av spilldesignelementer. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Forskningsprosjektet inngår i en masteroppgave i informatikk. Hensikten med studien er å studere effekten av spilldesign elementer. Forskningsspørsmålet er «*To what extent do players become more engaged when introducing game design elements?".*

Hvem er ansvarlig for forskningsprosjektet?
Institutt for datateknologi og informatikk ved NTNU er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Utvalget velges ved å kontakte tilfeldig aktuelle personer for undersøkelsen. Aktuelle deltakere er studenter og voksne i arbeid. Vi skal rekruttere ca. 30 personer.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du over to perioder (én periode varer i én uke) skal bruke spillet LetterLink, hvor du selv bestemmer hvor mye du ønsker å spille. Etter hver periode skal du fylle ut et spørreskjema. Det vil ta deg ca. 5 minutter. Spørreskjemaet inneholder påstander om hvordan du følte deg da du spilte spillet. Dine svar fra spørreskjemaet blir registrert elektronisk.

Videre vil det samles inn anonym data om brukere sin adferd på tjenesten, både når det kommer til brukerbasen som en helhet men også individuelle brukere.

Det er frivillig å delta
Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

Det er kun studentene Kristine Larssen og Andreas Amundsen som vil ha tilgang til opplysningene om deg. Navn og kontaktopplysningene dine vil vi erstatte med en kode som lagres på egen navneliste adskilt fra øvrige data. Navnelisten, som eneste dokument som inneholder personopplysninger i dette forskningsprosjektet, vil bli lagret på NTNU sine servere på en bruker med to-faktorautentisering.

Svarene fra spørreskjemaet blir bearbeidet av Nettskjema.

All data knyttet til spillet LetterLink blir bearbeidet av Google Firebase og analysert ved hjelp av Google Analytics. Dette gjøres helt anonymt og her vil det ikke lagres noen personopplysninger. Google kan derfor ikke identifisere deltakere.

Deltakerne vil bli anonymisert i oppgaven, og det vil derfor ikke være mulig å gjenkjenne deltagerne i masteroppgaven.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?
Prosjektet vil etter planen avsluttes 10. juni 2023. Etter prosjektslutt vil datamaterialet bli slettet.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Institutt for datateknologi og Informatikk ved NTNU har Sikt – Kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter
Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Veileder og førsteamanuensis ved institutt for datateknologi og Informatikk ved NTNU:
  - Boban Vesin, epost: boban.vesin@ntnu.no, telefon: +47 48 21 74 55
- Studentene:
  - Kristine Larssen, epost: krlarss@stud.ntnu.no, telefon: 98 83 41 80
  - Andreas Amundsen, epost: andramu@stud.ntnu.no, telefon: 98 89 97 24
- Vårt personvernombud:
  - Thomas Helgesen, Epost: thomas.helgesen@ntnu.no eller telefon: 93 07 90 38

Hvis du har spørsmål knyttet til vurderingen som er gjort av personverntjenestene fra Sikt, kan du ta kontakt via:

- Epost: personverntjenester@sikt.no eller telefon: 73 98 40 40.

Med vennlig hilsen

Boban Vesin (Veileder) *Kristine Larssen & Andreas Amundsen*

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet LetterLink - Effekten av spilldesign-elementer, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i å bruke spillet LetterLink over to perioder på én uke hver
- ☐ å delta i to spørreundersøkelser angående engasjement i spill
- ☐ å delta i indirekte anonym observasjon av brukeradferd

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

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(Signert av prosjektdeltaker, dato)

Appendix C - Email communication

C1: Template for email sent to the participants in week 1

Hei navn!

Da har første spilluke startet! 🥳 Den vil foregå frem til søndag 5 mars 23:59.

Logg inn på https://www.letterlink.no/. Ditt brukernavn og passord er:

[animal_name]@letterlink.no
[password]

Spillet kan spilles på både PC og mobil. Prøv gjerne begge deler og finn ut hvor du liker best å spille.

Vi ønsker ikke å legge noen føringer for hvor mye eller lite dere spiller. Det vi ønsker er at dere spiller tilstrekkelig nok til at dere kan svare på spørreundersøkelsen som vil bli sendt ut tidlig neste uke 🙌

Vi har laget en powerpoint med enkle instruksjoner hvordan man spiller 🤓: [...]

Dessverre så får dere ikke varslinger når det er deres tur. Vi anbefaler å sjekke innimellom om det er deres tur eller enda bedre spille ferdig et spill i en økt.

Verktøyene vi bruker for logging fungerer ikke med adblock. Dersom dere har adblock installert ønsker gjerne at dere skrur den av for LetterLink.

Lykke til og kontakt oss gjerne dersom det er noen spørsmål, ting som ikke fungerer eller andre tilbakemeldinger 🌟

Mvh
Andreas og Kristine

C2: Template for email sent to the participants in week 2

Hei!

Da var første spilluke over 🔥

Brukerne har blitt deaktivert, men blir aktivert igjen på mandag for neste og siste spilleuke 🙌🏻

Nå ønsker vi gjerne at dere svarer på spørreskjemaet innen 12 mars kl 23:59 🖊️ Det tar rundt 5 minutter å fylle ut skjemaet

Lenke til spørreskjemaet: https://nettskjema.no/a/323810

Mvh
Andreas og Kristine

C3: Template for email sent to the participants in week 3

Hei!

Da er andre og siste spilluke i gang! Den vil vare frem til **søndag 19. mars** 🥳

Nytt med denne uka er nye spill-elementer. Hva som er nytt kan dere se i vedlegget 🔥

Igjen så ønsker vi ikke å legge noen føringer for hvor mye eller lite dere spiller. Det vi ønsker er at dere spiller tilstrekkelig nok til at dere kan svare på spørreundersøkelsen som vil bli sendt ut tidlig neste uke 😇

Lykke til og kontakt oss dersom det er noen spørsmål, tilbakemeldinger eller om dere har glemt innloggingsinformasjonen 🌟

Mvh
Andreas og Kristine

C4: Template for e-mail sent to the participants in week 4

Hei!

Da var andre og siste spilleuke over 😭

Vi ønsker at dere svarer på spørreskjemaet innen **26 mars kl 23:59** 📅

Lenke til spørreskjema: https://nettskjema.no/a/327103

Tusen takk for din deltakelse i prosjektet! All data vil bli slettet innen midten av juni 2023 🙌🏻

Send oss en mail dersom du fortsatt har lyst til å spille spillet, så gir vi deg tilgang.

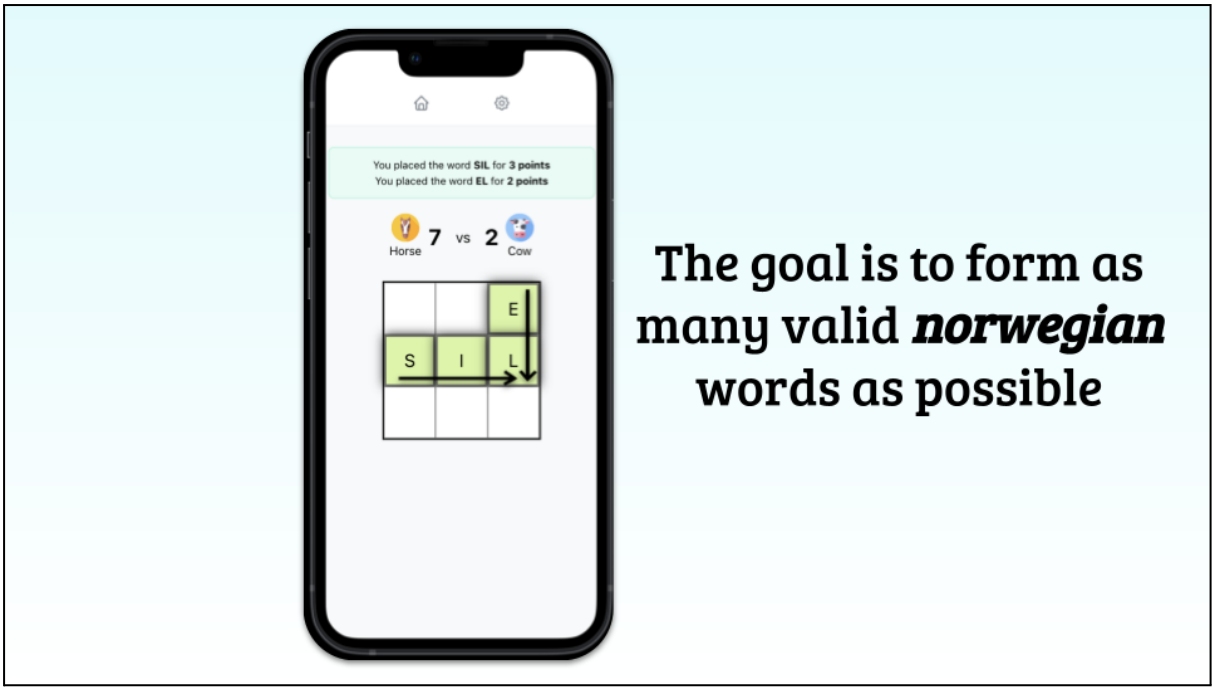
Mvh
Andreas og Kristine

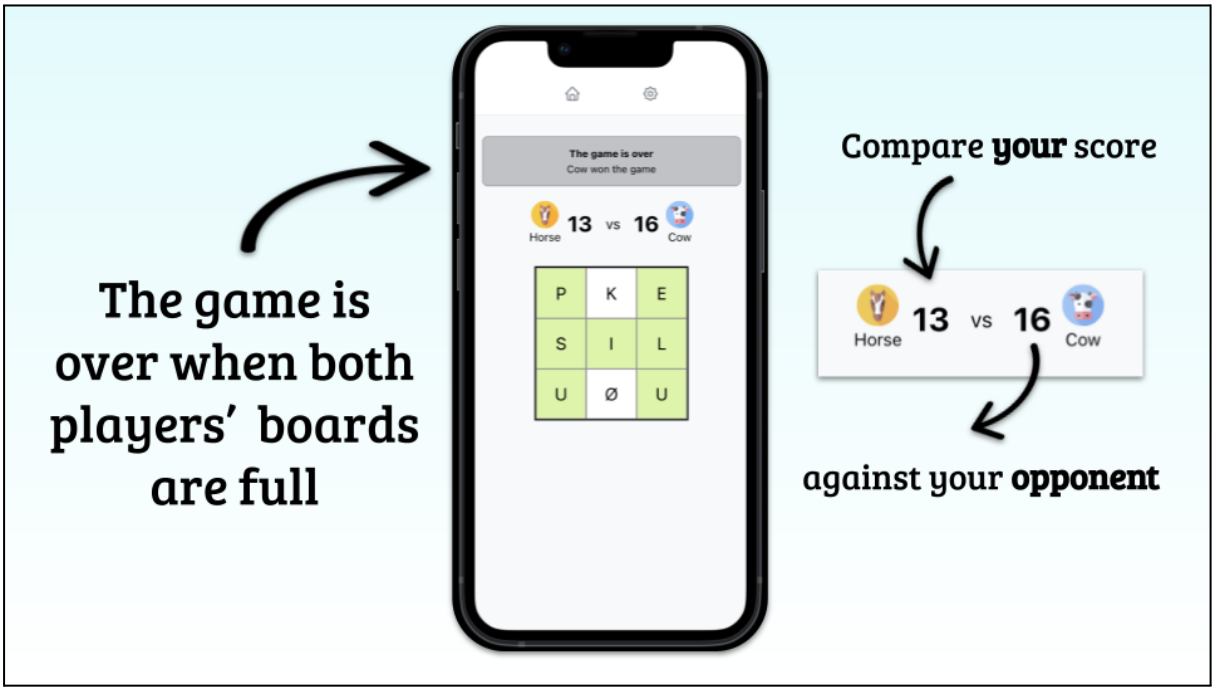
Appendix D - Application guide week 1

Introduction

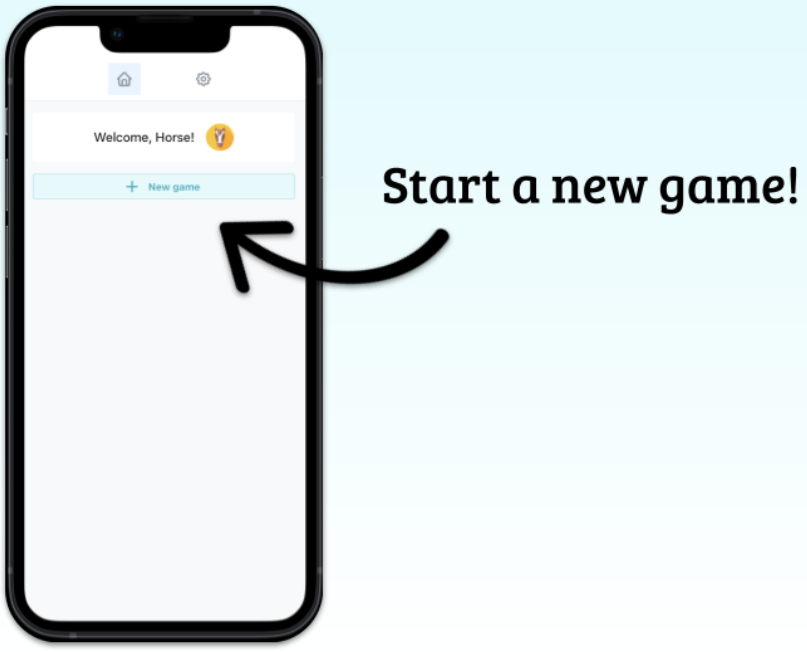
This is your own ***personal*** board

Your opponent has their own board, **hidden** from you!

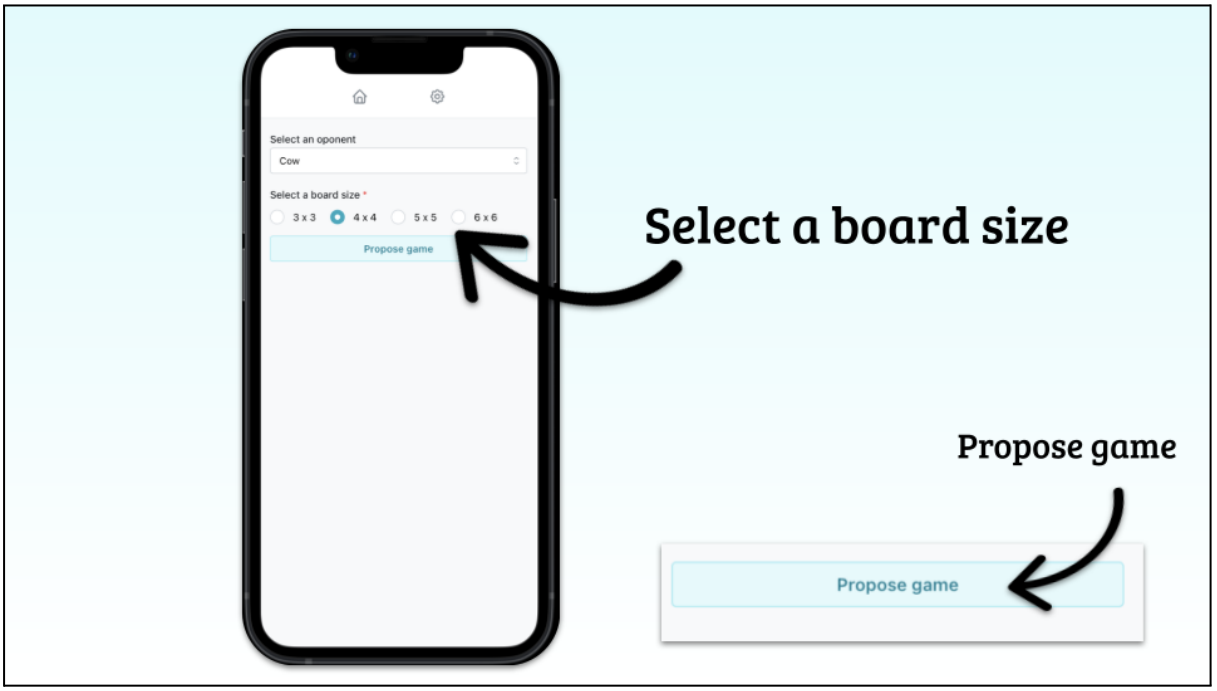

You placed the word SIL for 3 points
You placed the word EL for 2 points
Horse 7 vs 2 Cow
E
S I L
The goal is to form as many valid norwegian words as possible


The game is over when both players' boards are full
The game is over
Cow won the game
Horse 13 vs 16 Cow
P K E
S I L
U Ø U
Compare your score
Horse 13 vs 16 Cow
against your opponent

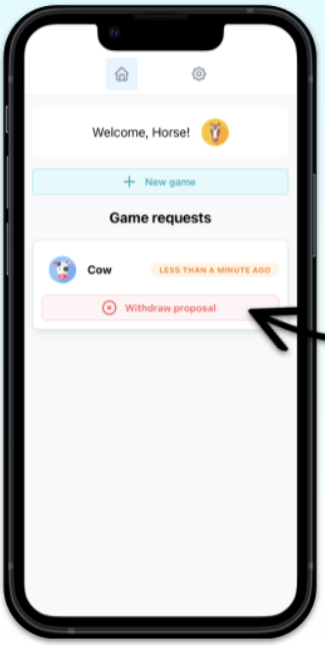
Start a game




Select an oponent
Cow
Propose game
Select an opponent!

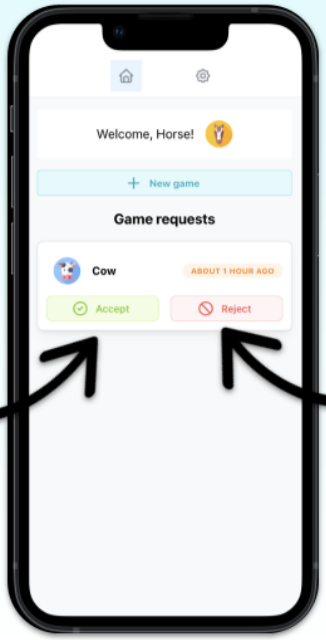

Select an oponent
Cow
Select a board size *
3 x 3
4 x 4
5 x 5
6 x 6
Propose game
Select a board size
Propose game
Propose game

Wait for your opponent to approve your request



Withdraw proposal

Receive game requests from other players

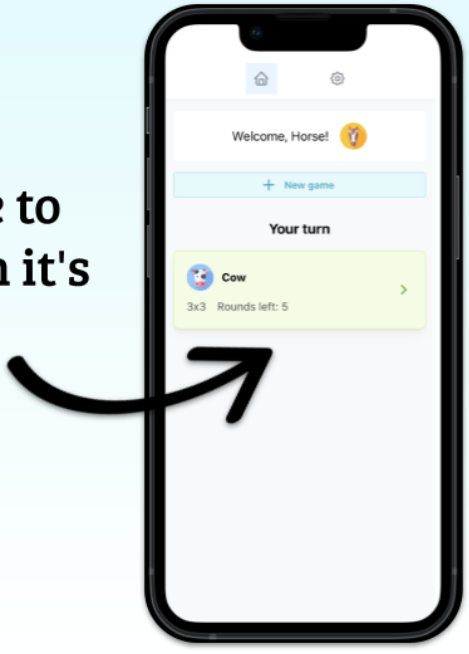


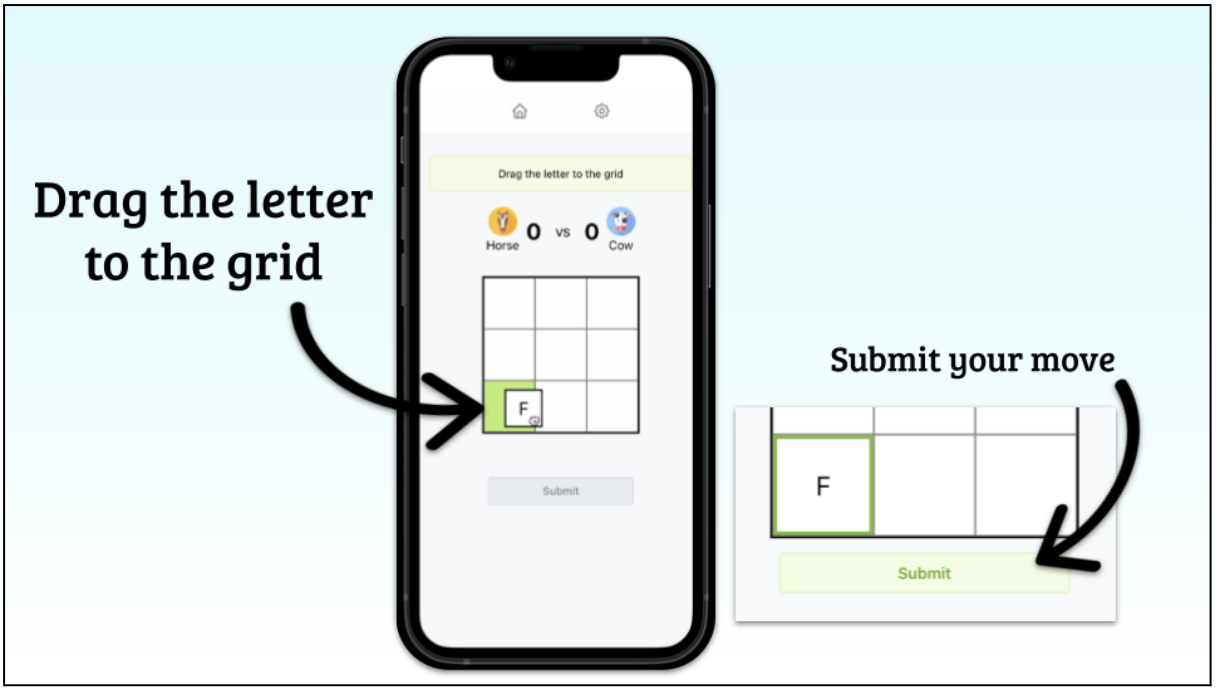
Accept

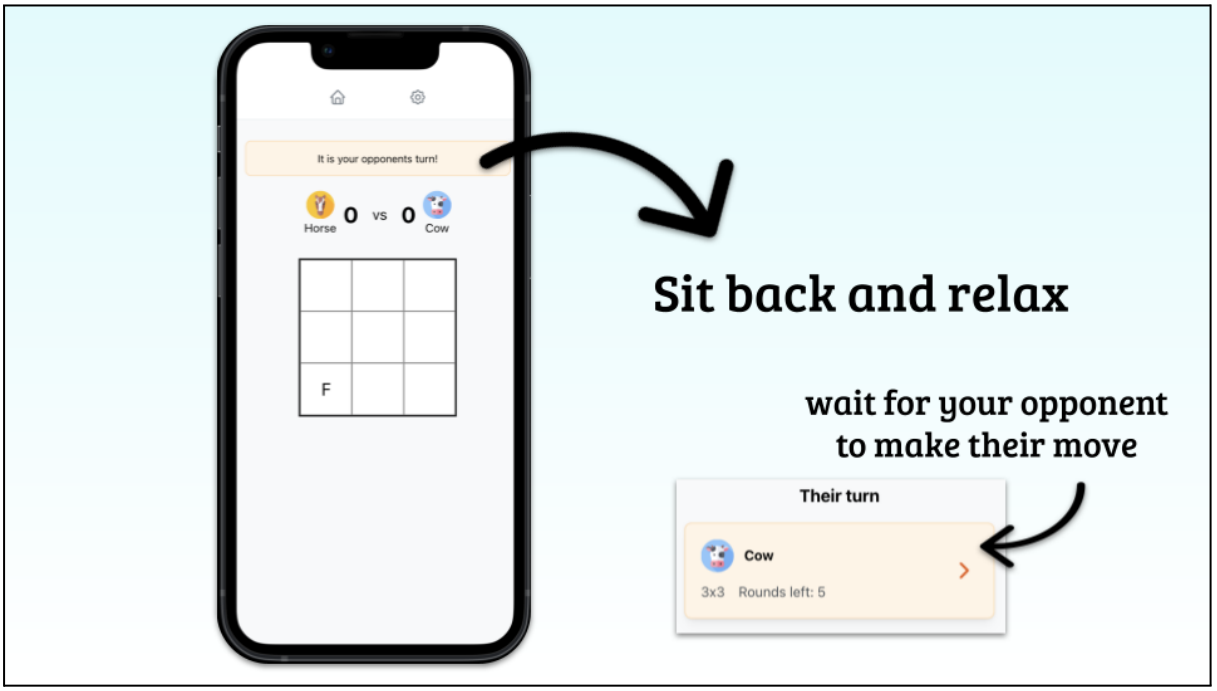
or *reject* it

How to play

Click on the game to make a move when it's your turn

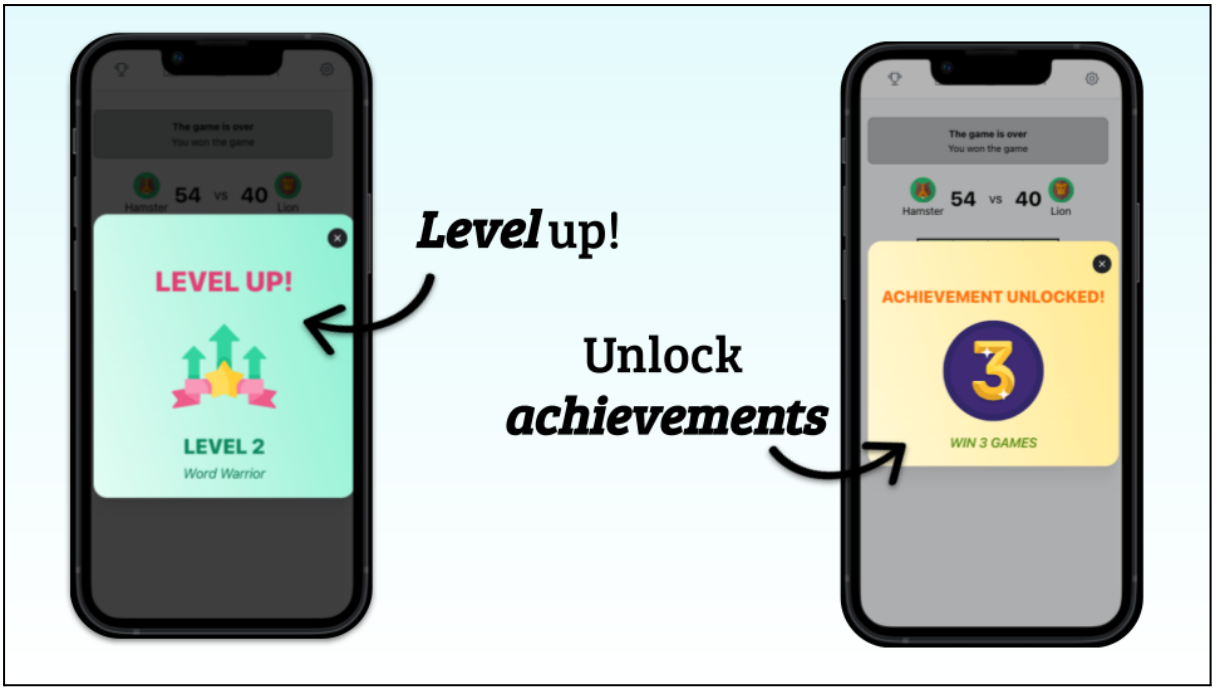


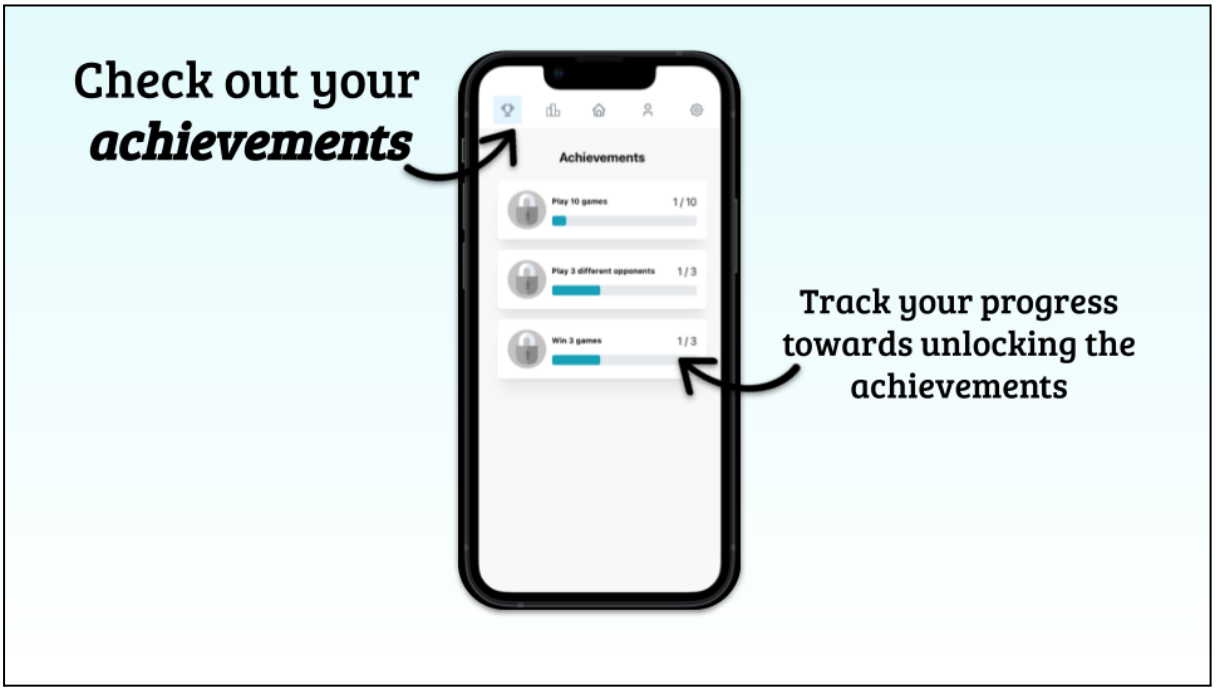

Drag the letter to the grid
Drag the letter to the grid
Horse 0 vs 0 Cow
F
Submit
Submit your move
F
Submit


It is your opponents turn!
Horse 0 vs 0 Cow
F
Sit back and relax
wait for your opponent to make their move
Their turn
Cow
3x3 Rounds left: 5

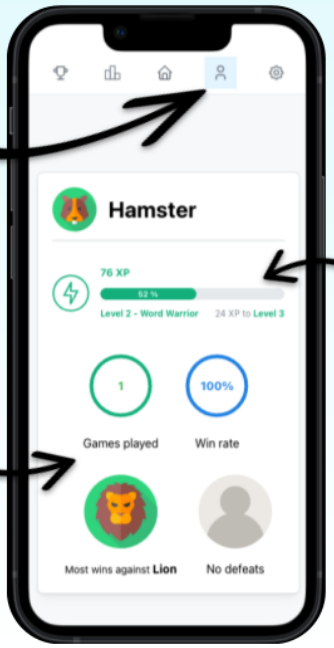
Appendix E - Application guide week 2

New features


The game is over
You won the game
Hamster
54
vs
40
Lion
LEVEL UP!
LEVEL 2
Word Warrior
Level up!
Unlock
achievements
ACHIEVEMENT UNLOCKED!
3
WIN 3 GAMES


Check out your
achievements
Achievements
Play 10 games
1 / 10
Play 3 different opponents
1 / 3
Win 3 games
1 / 3
Track your progress
towards unlocking the
achievements

Check out your **profile**



Level up by gain XP by completing games

Keep track on your game statistics

Compare your score against the other players

Are you the best player in this game?

Appendix F - Questionnaire Week 1

LetterLink - Survey of game experience part 1

Side 1

Obligatoriske felter er merket med stjerne *

The first week of playing is over. Thanks for taking the time to play the game - we appreciate it.

The next step is to fill out this survey. It will take approximately 5 minutes.

First, we want to collect some information about you. Please fill in your username so we can connect the answers with your in-game behavior and the responses from the following survey.

After that, we want you to rank how well the statements describe how you felt while playing the game.

Sideskift

Side 2

Obligatoriske felter er merket med stjerne *

Your animal username from the game *

Age *

Gender *

- Girl
- Boy
- Other

How often do you play games (like video games, board games, mobile games etc.) weekly? *

- None
- 30 minutes
- 1 hour
- 2 hours
- more than 3 hours

Sideskift

Obligatoriske felter er merket med stjerne *

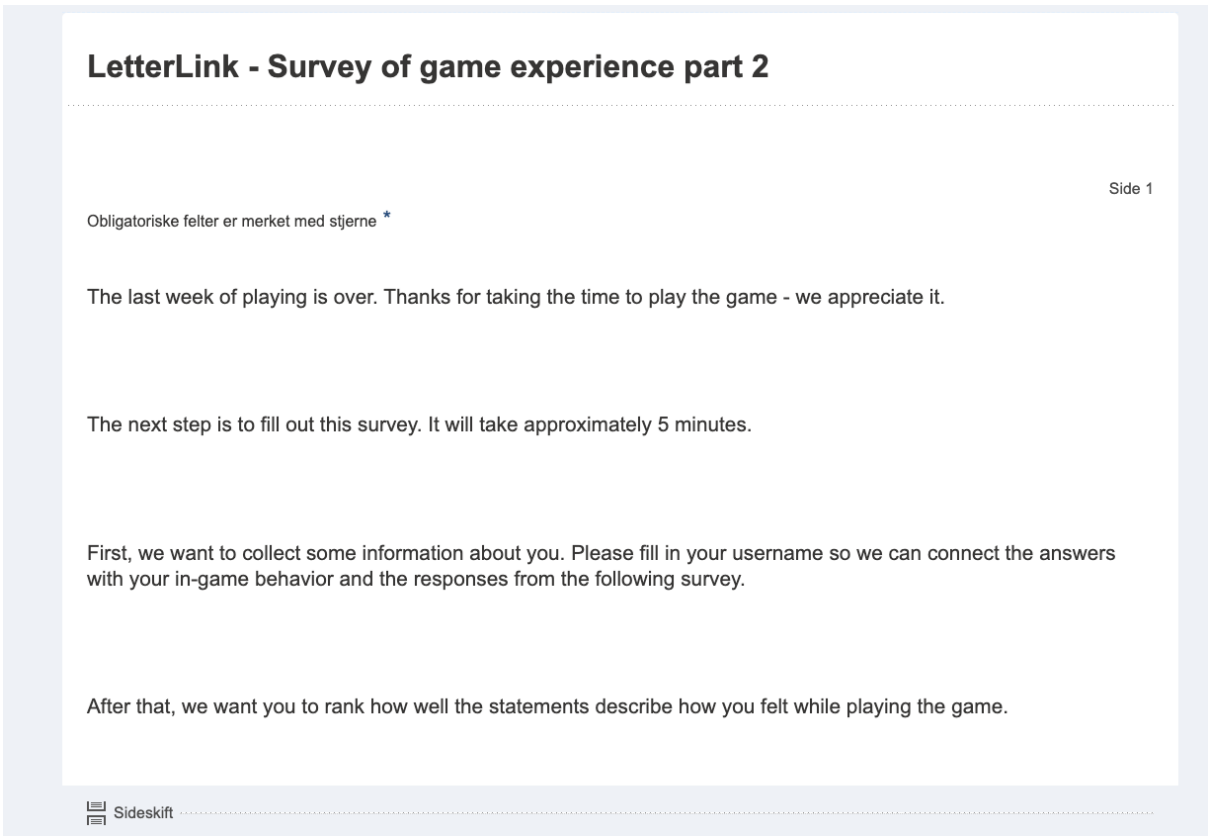
Please indicate how you felt while playing the game for each of the items, on the following scale:

	1 - Not at all	2 - Slightly	3 - Moderately	4 - Fairly	5 - Extremely
I felt content *	○	○	○	○	○
I felt skilful *	○	○	○	○	○
I was interested in the game's story *	○	○	○	○	○
I thought it was fun *	○	○	○	○	○
I was fully occupied with the game *	○	○	○	○	○
I felt happy *	○	○	○	○	○
It gave me a bad mood *	○	○	○	○	○
I thought about other things *	○	○	○	○	○
I found it tiresome *	○	○	○	○	○
I felt competent *	○	○	○	○	○
I thought it was hard *	○	○	○	○	○
It was aesthetically pleasing *	○	○	○	○	○
I forgot everything around me *	○	○	○	○	○
I felt good *	○	○	○	○	○
I was good at it *	○	○	○	○	○
I felt bored *	○	○	○	○	○
I felt successful *	○	○	○	○	○

I felt imaginative *	○	○	○	○	○
I felt that I could explore things *	○	○	○	○	○
I enjoyed it *	○	○	○	○	○
I was fast at reaching the game's targets *	○	○	○	○	○
I felt annoyed *	○	○	○	○	○
I felt pressured *	○	○	○	○	○
I felt irritable *	○	○	○	○	○
I lost track of time *	○	○	○	○	○
I felt challenged *	○	○	○	○	○
I found it impressive *	○	○	○	○	○
I was deeply concentrated in the game *	○	○	○	○	○
I felt frustrated *	○	○	○	○	○
It felt like a rich experience *	○	○	○	○	○
I lost connection with the outside world *	○	○	○	○	○
I felt time pressure *	○	○	○	○	○
I had to put a lot of effort into it *	○	○	○	○	○

Sideskift

Appendix G - Questionnaire Week 2



LetterLink - Survey of game experience part 2

Side 1

Obligatoriske felter er merket med stjerne *

The last week of playing is over. Thanks for taking the time to play the game - we appreciate it.

The next step is to fill out this survey. It will take approximately 5 minutes.

First, we want to collect some information about you. Please fill in your username so we can connect the answers with your in-game behavior and the responses from the following survey.

After that, we want you to rank how well the statements describe how you felt while playing the game.

Sideskift

Side 2

Obligatoriske felter er merket med stjerne *

Your animal username from the game *

Sideskift

Obligatoriske felter er merket med stjerne *

Please indicate how you felt while playing the game for each of the items, on the following scale:

	1 - Not at all	2 - Slightly	3 - Moderately	4 - Fairly	5 - Extremely
I felt content *	○	○	○	○	○
I felt skilful *	○	○	○	○	○
I was interested in the game's story *	○	○	○	○	○
I thought it was fun *	○	○	○	○	○
I was fully occupied with the game *	○	○	○	○	○
I felt happy *	○	○	○	○	○
It gave me a bad mood *	○	○	○	○	○
I thought about other things *	○	○	○	○	○
I found it tiresome *	○	○	○	○	○
I felt competent *	○	○	○	○	○
I thought it was hard *	○	○	○	○	○
It was aesthetically pleasing *	○	○	○	○	○
I forgot everything around me *	○	○	○	○	○
I felt good *	○	○	○	○	○
I was good at it *	○	○	○	○	○
I felt bored *	○	○	○	○	○
I felt successful *	○	○	○	○	○

I felt imaginative *	○	○	○	○	○
I felt that I could explore things *	○	○	○	○	○
I enjoyed it *	○	○	○	○	○
I was fast at reaching the game's targets *	○	○	○	○	○
I felt annoyed *	○	○	○	○	○
I felt pressured *	○	○	○	○	○
I felt irritable *	○	○	○	○	○
I lost track of time *	○	○	○	○	○
I felt challenged *	○	○	○	○	○
I found it impressive *	○	○	○	○	○
I was deeply concentrated in the game *	○	○	○	○	○
I felt frustrated *	○	○	○	○	○
It felt like a rich experience *	○	○	○	○	○
I lost connection with the outside world *	○	○	○	○	○
I felt time pressure *	○	○	○	○	○
I had to put a lot of effort into it *	○	○	○	○	○

Sideskift

Side 5

Obligatoriske felter er merket med stjerne *

Gamification includes various game design elements intended to influence your level of motivation.

For EACH of the game design elements presented in the following pages, respond to the following statement:

"In this game, due to the (***game design element),*** I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without the (*game design element*)."

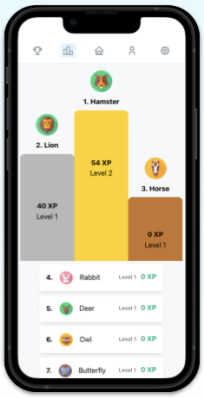
Sideskift

Side 6

Obligatoriske felter er merket med stjerne *

In this game, due to the **leaderboard**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without the leaderboard.

	Much Less	Less	Neither Less or More	More	Much More
Leaderboard *	○	○	○	○	○



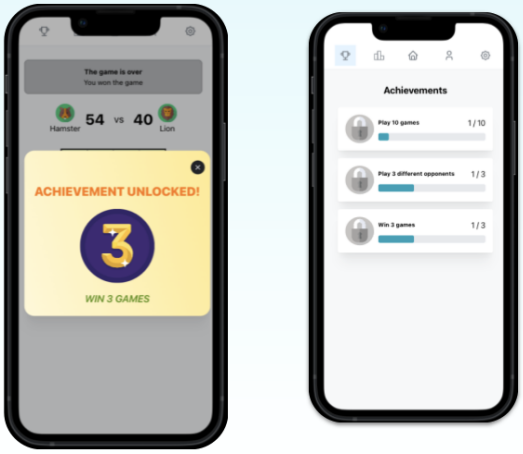
Sideskift

Side 7

Obligatoriske felter er merket med stjerne *

In this game, due to **achievements**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without achievements.

	Much Less	Less	Neither Less or More	More	Much More
Achievements *	○	○	○	○	○



Sideskift

Side 8

Obligatoriske felter er merket med stjerne *

In this game, due to **confetti animation**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without confetti animation.

	Much Less	Less	Neither Less or More	More	Much More
Confetti animation *	○	○	○	○	○

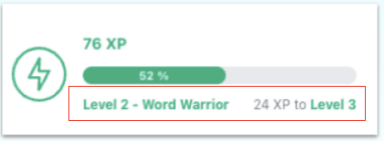
Sideskift

Side 9

Obligatoriske felter er merket med stjerne *

In this game, due to **levels**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without levels.

	Much Less	Less	Neither Less or More	More	Much More
Levels *	○	○	○	○	○



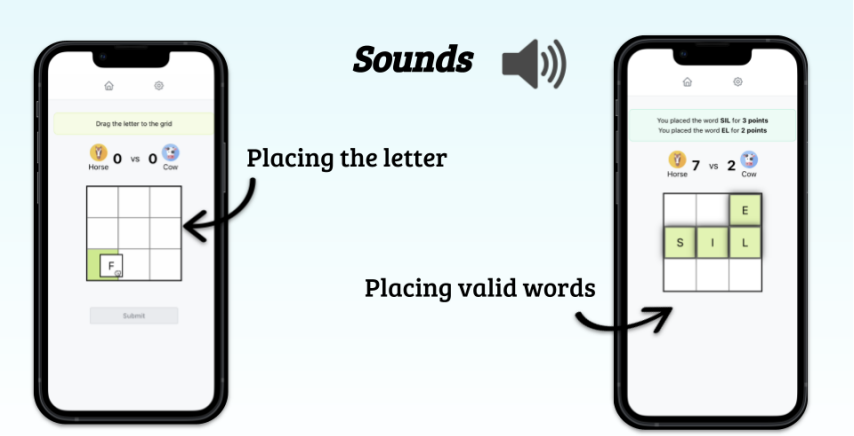
Sideskift

Side 10

Obligatoriske felter er merket med stjerne *

In this game, due to **sounds**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without sounds.

	Much Less	Less	Neither Less or More	More	Much More
Sounds *	○	○	○	○	○



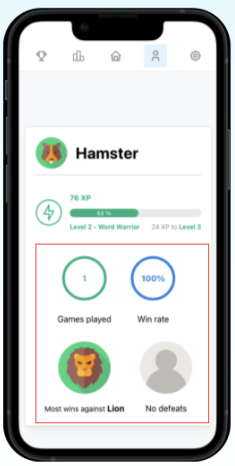
Sideskift

Side 11

Obligatoriske felter er merket med stjerne *

In this game, due to **profile statistics**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without profile statistics.

	Much Less	Less	Neither Less or More	More	Much More
Profile statistics *	○	○	○	○	○



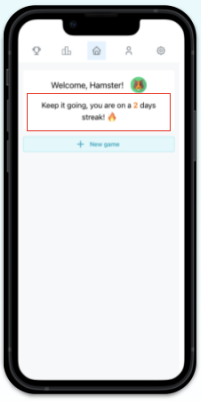
Sideskift

Side 12

Obligatoriske felter er merket med stjerne *

In this game, due to **streaks**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without streaks.

	Much Less	Less	Neither Less or More	More	Much More
Streaks *	○	○	○	○	○



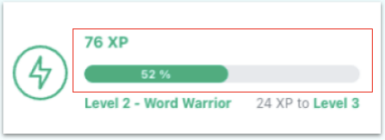
Sideskift

Side 13

Obligatoriske felter er merket med stjerne *

In this game, due to **experience points (XP)**, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing this game without experience points (XP).

	Much Less	Less	Neither Less or More	More	Much More
Experience points (XP) *	○	○	○	○	○



Sideskift

Obligatoriske felter er merket med stjerne *

Overall, due to the game design elements mentioned previously, I was [*much less, less, neither less or more, more, much more*] motivated to play the game compared to playing the game without the game design elements.

	Much Less	Less	Neither Less or More	More	Much More
Overall *	○	○	○	○	○

Appendix H - GameFlow Criteria

Element	Criteria
Concentration	● games should provide a lot of stimuli from different sources ● games must provide stimuli that are worth attending to ● games should quickly grab the players' attention and maintain their focus throughout the game - players shouldn't be burdened with tasks that don't feel important ● games should have a high workload, while still being appropriate for the players' perceptual, cognitive, and memory limits ● players should not be distracted from tasks that they want or need to concentrate on
Challenge	● challenges in games must match the players' skill levels ● games should provide different levels of challenge for different players ● the level of challenge should increase as the player progresses through the game and increases their skill level ● games should provide new challenges at an appropriate pace
Player skills	● players should be able to start playing the game without reading the manual ● learning the game should not be boring, but be part of the fun ● games should include online help so players don't need to exit the game ● players should be taught to play the game through tutorials or initial levels that feel like playing the game ● games should increase the players' skills at an appropriate pace as they progress through the game ● players should be rewarded appropriately for their effort and skill development ● game interfaces and mechanics should be easy to learn and use
Control	● players should feel a sense of control over their characters or units and their movements and interactions in the game world

	● players should feel a sense of control over the game interface and input devices ● players should feel a sense of control over the game shell (starting, stopping, saving, etc.) ● players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors ● players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world) ● players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers)
Clear goals	● overriding goals should be clear and presented early ● intermediate goals should be clear and presented at appropriate times
Feedback	● players should receive feedback on progress toward their goals ● players should receive immediate feedback on their actions ● players should always know their status or score
Immersion	● players should become less aware of their surroundings ● players should become less self-aware and less worried about everyday life or self ● players should experience an altered sense of time ● players should feel emotionally involved in the game ● players should feel viscerally involved in the game
Social interaction	● games should support competition and cooperation between players ● games should support social interaction between players (chat, etc.) ● games should support social communities inside and outside the game

Appendix I - Explanation of variables

Log data

Week 1 - Without game elements	Week 2 - With game elements	Description
A_games	B_games	Number of games (active and ended)
A_proposed_games_list	B_proposed_games_list	Length of the list of proposed games, both sent and received proposals
A_XP	B_XP	Amount of experience points gathered in total by the player. One in-game point equals one experience point. Experience points are only added if the game was finished
A_lost_games	B_lost_games	Number of games the player has lost
A_wins	B_wins	Number of games the player has won
A_oppo_end	B_oppo_end	Number of unique opponents the player has finished game with
	B_streaks	Number of consecutive days the player has been playing. Resets when the player does not play for 24 hours
A_proposed_games	B_proposed_games	Number of games the player has proposed
A_recievd_proposals	B_recievd_proposals	Number of game proposals the player has received from other players
A_draw	B_draw	Number of games that resulted in a draw
A_ended_games	B_ended_games	Number of games that were finished
A_active_games	B_active_games	Number of active games that are yet to be finished
A_not_active	B_not_active	Number of games that have not been started yet, caused by players not yet accepting a proposed game
A_days_visit	B_days_visit	Number of days the player did a move in-game
A_total_points	B_total_points	Number of total points obtained by the player. Includes points obtained in unfinished games

Data collected from the questionnaire

Demographic

Variables - Questionnaire week 1	Variables - Questionnaire week 2	Description
Username	Username	Unique username - a given animal name
age		Age of the player
gender		Gender (male = 0, female = 1)
time_playing_weekly		Time spent playing games per week (1 = None, 2 = 30min, 3 = 1h, 4 = 2h, 5 = more than 3h)

Game experience questionnaire (GEQ)

1 = not at all, 2 = alightly, 3 = moderately, 3= fairly, 4 = extremely

Variable - Questionnaire week 1	Variable - Questionnaire week 2	Question	Component
W1_P_content	W2_P_content	I felt content	Positive affect
W1_P_fun	W2_P_fun	I thought it was fun	Positive affect
W1_P_felt_good	W2_P_happy	I felt good	Positive affect
W1_P_happy	W2_P_felt_good	I felt happy	Positive affect
W1_P_enjoyed_it	W2_P_enjoyed_it	I enjoyed it	Positive affect
W1_CO_skilful	W2_CO_skilful	I felt skilful	Competence
W1_CO_competent	W2_CO_competent	I felt competent	Competence
W1_CO_good_at_it	W2_CO_good_at_it	I was good at it	Competence
W1_CO_succsessful	W2_CO_succsessful	I felt successful	Competence
W1_CO_fast_reach_target	W2_CO_fast_reach_target	I was fast at reaching the game's targets	Competence
W1_SI_interested_game_story	W2_SI_interested_game_story	I was interested in the game's story	Sensory and immaginative immersion
W1_SI_aestetical_pleasing	W2_SI_aestetical_pleasing	It was aesthetically pleasing	Sensory and immaginative immersion
W1_SI_imaginative	W2_SI_imaginative	I felt imaginative	Sensory and

			immaginative immersion
W1_SI_explore_things	W2_SI_explore_things	I felt that I could explore things	Sensory and immaginative immersion
W1_SI_impressive	W2_SI_impressive	I found it impressive	Sensory and immaginative immersion
W1_SI_rich_experience	W2_SI_rich_experience	It felt like a rich experience	Sensory and immaginative immersion
W1_F_occupied_with_game	W2_F_occupied_with_game	I was fully occupied with the game	Flow
W1_F_forgot_everything_around	W2_F_forgot_everything_around	I forgot everything around me	Flow
W1_F_lost_track_time	W2_F_lost_track_time	I lost track of time	Flow
W1_F_concentrated	W2_F_concentrated	I was deeply concentrated in the game	Flow
W1_F_lost_connection	W2_F_lost_connection	I lost connection with the outside world	Flow
W1_N_bad_mood	W2_N_bad_mood	It gave me a bad mood	Negative affect
W1_N_thought_other_things	W2_N_thought_other_things	I thought about other things	Negative affect
W1_N_tiresome	W2_N_tiresome	I found it tiresome	Negative affect
W1_N_bored	W2_N_bored	I felt bored	Negative affect
W1_CH_it_was_hard	W2_CH_it_was_hard	I thought it was hard	Challenge
W1_CH_pressured	W2_CH_pressured	I felt pressured	Challenge
W1_CH_challenged	W2_CH_challenged	I felt challenged	Challenge
W1_CH_time_pressure	W2_CH_time_pressure	I felt time pressure	Challenge
W1_CH_lot_effort	W2_CH_lot_effort	I had to put a lot of effort into it	Challenge
W1_T_annoyed	W2_T_annoyed	I felt annoyed	Tension/Annoyance
W1_T_irritable	W2_T_irritable	I felt irritable	Tension/Annoyance
W1_T_frustrated	W2_T_frustrated	I felt frustrated	Tension/Annoyance

Motivational impact of game design elements

1 = much less, 2 = less, 3 = Neither Less or More, 4 = more, 5 = much more

Variable - Questionnaire week 2	Description
Confetti_animations	How much motivated the player were to continue play the game when the game design element was present.
Leaderboard	How much motivated the player were to continue play the game when the game design element was present.
Achievements	How much motivated the player were to continue play the game when the game design element was present.
Levels	How much motivated the player was to continue play the game when the game design element was present.
Sounds	How much motivated the player were to continue play the game when the game design element was present.
Profile_statistics	How much motivated the player were to continue play the game when the game design element was present.
Streaks	How much motivated the player were to continue play the game when the game design element was present.
Experience_points	How much motivated the player were to continue play the game when the game design element was present.
Overall_motivation	How much motivated the player were to continue play the game when all the game design elements were present.

Computed variables

Average score is computed for each engagement component in GEQ

Score in week 1	Score in week 2	Engagement component
W1_P	W2_P	**Positive affect** - Average score
W1_CO	W2_CO	**Competence** - Average score
W1_SI	W2_SI	**Sensory and imaginative immerison** - Average score
W1_F	W2_F	**Flow** - Average score
W1_N	W2_N	**Negative affect** - Average score
W1_CH	W2_CH	**Challenge** - Average score
W1_T	W2_T	**Tension/Annoyance** Average score

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