Fill in the World: gamification in children's online language learning

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Abstract

This project is about the design, implementation, and evaluation of "Fill In The World" – a gamified language learning application for primary school children. The game allows children to learn English vocabulary through creative and collaborative exploration, unlike any of the explored existing applications. Following usability evaluation, it was established that the game still needs to be improved and extended before it could be implemented in classrooms or used for research about the effectiveness of individual gamification elements.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Vidminas Mikučionis*)

Acknowledgements

I want to give a big shout out to Professor Judy Robertson, my undergraduate supervisor, who a few years ago asked me the question “why do computer scientists not want to teach?”. This question stuck with me and contributed to the idea for this project, while her wise advice and careful guidance made it possible.

Special mentions are well deserved by my closest friends Stefani Tirkova and Adrián Doña Mateo, with whom we have survived this challenging year; my mother, who helped me realise that yet another game for learning maths or programming would not be as interesting as language learning, which has not been explored as much; and my new friend Amy Rodger who helped with sage tips about how to get this project done without losing my mind over little details.

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Contents

Chapter 1

Introduction

1.1 Motivation

Language learning is one of the most important human skills. First language acquisition from a young age is necessary for normal brain development (Vyshedskiy et al., 2017) and mastery of multiple languages is required for communication in multilingual societies. Luxembourg, for example, being a small country bordering Belgium, France and Germany, has three national languages: Luxembourgish, German, and French, which are taught in schools for children aged 4, 6, and 7 respectively.

Learning multiple languages is also important in monolingual societies. Exposure to foreign languages from a young age boosts awareness of other cultures and makes it easier to travel internationally. Multilingualism is also linked to benefits in children's cognitive abilities (Fürst and Grin, 2017), even with second-language learners (Baumgart and Billick, 2017), which is the motivation behind Scotland's 1+2 language learning approach (Scottish Government, 2012).

Traditionally, primary school children are taught languages in face-to-face settings, such as school classrooms. However, in the last two decades, numerous technological tools and platforms that facilitate online language learning have emerged, like Duolingo[1], Memrise[2] or Mondly[3]. Online learning platforms have become especially important in the wake of Covid-19, which forced teachers and learners to conduct lessons remotely from home.

Learning fully remotely comes with a set of new challenges: learners may struggle with motivation to study from home, teachers have far less information about their pupils' situations, and creating interesting online activities can take more time and expertise.

Current applications use gamification elements to make them more fun to use, but these are mostly extrinsic rewards that inhibit learners' intrinsic motivation to study, which can be harmful in the long term.

[1] https://www.duolingo.com
[2] https://www.memrise.com
[3] https://www.mondly.com

1.2 Project goals

This project focuses on supporting primary school children's online second language learning using gamification elements that foster intrinsic motivation. The project goal was to **design, develop, and evaluate the usability of an educational game for learning vocabulary** and investigate the research question **"would a gamified learning application be viable for a future study about the effectiveness of individual gamification elements?"**.

1.3 Report structure

Chapter 2. Background explores the context of online learning applications and existing gamification research.

Chapter 3. Game conceptualisation details the conceptual idea of a game called "Fill In The World" – how it is rooted in educational and gamification theory and what is important in making the game work well for children.

Chapters 4. Application design and 5. Implementation explain the process of how a full prototype of "Fill In The World" was developed.

Chapter 6. Evaluation and Discussion is about the usability evaluation "Fill In The World" with families, which showed that the usability of the game must be improved before it could be taken further into studies of the under-researched area of the impact of gamification elements in education.

The final game prototype shows promise that it could be used in investigating gamification elements due to the extensibility of its concept. Although many usability improvements are still needed, concrete next steps are suggested in chapter 7. Reflection and Further Work.

Chapter 2

Background

This chapter explores the context of language learning, online learning applications and existing gamification research, which highlight important design requirements and approaches to evaluation.

2.1 Children's foreign language acquisition

This project aims to support children's Foreign Language (FL) learning, starting with English, although other languages could be added in the future.

One may argue that language learning is especially important for children – the Critical Period Hypothesis claims that there is an optimal age range during which children are best suited to learn new abilities (including speaking languages), but there is sufficient evidence showing that this is not true for FL learning (Nikolov and Djigunovic, 2006).

However, there do seem to be differences in how children and adults learn languages – children benefit more from meaning-focused activities and rely more on memory rather than inductive or deductive reasoning. Rice (1989) reason that the best way to support children's language learning is to "provide many opportunities for a child to interact with objects and events and other children."

An application supporting language learning for children should therefore focus on helping them to memorise vocabulary about objects and events that can be used for something meaningful, and allow interacting with other children.

2.2 Online vs face-to-face learning

2.2.1 Impact on learners

Gasevic et al. (2015, pp.34, 114) in a review of meta-analyses of distance education show that it is "more effective, or at least as effective as traditional classroom instruction". But the authors also found that distance learning usually requires more effort from teachers to support learners than with face-to-face activities.

Hattie's collection of education meta-analyses (2008, p.232) concurs with the conclusion that there are no significant differences in learning outcomes between distance and traditional classes. Another trend is noted: that distance learners overall are less engaged with their courses than face-to-face learning students.

These observations set three foundational criteria that constitute effective online learning:

1. **Learning outcomes**: online learning should result in the same (or better) learning outcomes than face-to-face learning
2. **Implementation time**: the time required from teachers to create and work with online activities should not exceed what is involved in traditional teaching
3. **Learner engagement**: online learning activities should be at least as engaging as face-to-face ones

Learner engagement is closely linked to learning outcomes – "people usually accumulate information without trying, in the course of engaging in interesting experiences" writes Smith (2012, p.55). But this does not imply a direct correlation between the two, for example, a study by Muis et al. (2015) shows that immediate feedback with kindergarten learners reduced enjoyment but improved achievement.

Measuring impact on all three criteria is key for a real-world educational app implementation project.

2.2.2 Impact on the digital divide

Online learning has an disproportionate negative impact on learners from disadvantaged backgrounds, because they may not have access to good internet or required devices. This creates a digital divide between those who can learn and progress with the technology they have access to, and those who cannot follow.

This year's special Covid-19 circumstances exacerbated the impact on the digital divide (a recent OECD report states that "children from better-off families spent 30% more time on home learning than those from poorer families during the lockdown" (OECD, 2020)), which is why government and charity initiatives in the UK stepped in to mitigate this – many students from disadvantaged backgrounds received devices and support to help study from home (Scottish Government, 2020; Connecting Scotland, 2021; UK Department for Education, 2021).

To avoid contributing to the digital divide, any online learning application must be designed with cross-compatibility and accessibility in mind. This is important right from the start, because changing the compatibility of an application often requires completely rewriting it from scratch.

2.3 Gamified vs traditional distance learning

A promising method to improve learning outcome attainment and student engagement is gamification, defined by Deterding et al. (2011, p.9) as "the use of game design ele-

ments in non-game contexts". When game elements are introduced in education, this is called "gamified learning". Gamification in education is typically used to "motivate players to engage in a task they otherwise would not find attractive" (Plass et al., 2015, p.259).

Gamification has been applied in many contexts, such as health, business, sustainability, orientation, marketing, crowdsourcing, and social networks with positive results (Pereira et al., 2014; Conley and Donaldson, 2015; Seaborn and Fels, 2015). However, results about the effectiveness of gamified learning from different research studies are conflicting. For example, a high-quality longitudinal study by Hanus and Fox (2015) shows that "over time, gamified students were less motivated, empowered, and satisfied". The authors hypothesise that this may be due to external rewards that decreased students' intrinsic motivation to study. On the other hand, a recent meta-analysis by Sailer and Homner (2019) shows that gamified learning has "significant small effects" on cognitive, motivational, and behavioural learning outcomes, but concludes that "factors contributing to successful gamification are still somewhat unresolved, especially for cognitive learning outcomes".

Plass et al. (2015) suggest that different studies come to different conclusions based on whether they take a cognitive or sociocultural perspective on the distal goals and which moderator variables are considered. More evidence about the effectiveness of gamified learning is needed, despite the hundreds of published works in this field (Landers et al., 2018). A key issue in gathering quality evidence is that gamification approaches are time consuming and difficult to implement (Dicheva et al., 2015). This deters teachers from gamifying learning activities, especially those who lack confidence in their computer skills (Brooks et al., 2019). Without common practical implementations in classrooms, there are few reference points to base gamified learning research studies on – studies take highly varied approaches, which results in incomparable research findings.

According to a study by Linehan et al. (2011), implementations of gamification that consistently help learners to achieve more are those that increase intrinsic motivation.

An online learning application could target these issues if it was designed to be extensible for different purposes and if teachers could use it to support their learning activities without needing much time or programming knowledge. This application could also collect consistent data about learners' progress and engagement to help teachers keep track of their students. In the future, this could be used to measure the impact of individual gamification elements, by adding or removing them from the application.

2.4 Common gamification elements

Gamification implementation can be broken down into a range of different game design elements. Dicheva et al. (2015) and Dreimane (2019) formulate gamification frameworks that include:

- Points, which serve as rewards for accomplishments

- Milestones, such as Badges, Trophies or Achievements, as visual representations of accomplishments
- Leaderboards, where players can view their rank compared to other players or their own previous plays
- Performance Graphs, which allow players to see information about their performance during gameplay and compare it with previous results (often used in simulation games)
- Avatars, as visual representations of players
- Co-operation, for example with teams and teammates
- Side Narratives, stories about activities and characters in the game, which don't relate to the player
- Virtual currency, which players can obtain by accomplishing tasks. Players can use virtual currency to purchase virtual (or physical) rewards of their own choice
- Progress Bars and Levels, which allow players to get instant feedback on their rate of progress

There are many other gamification elements beyond this framework, but these are the most common ones according to the authors. To this list, I would add four more elements that I have observed in learning games in subsection 3.1.1. Gamified language learning:

- Encouragements, such as confetti, congratulations, or other rewards that are neither points nor badges/trophies/achievements
- Winning Streaks, which show how many days in a row a player has successfully completed some task, and encourages players to keep regularly progressing
- Personal Goals, allowing players to decide their own target outcomes and track progress towards them
- Health Points, like points, except they are full at the beginning and players lose them for negative actions (such as mistakes)

Out of all these elements, most are external rewards that increase extrinsic motivation of players, but the ones that could foster intrinsic motivation are performance graphs, personal goals, co-operation, and side narratives, because they are not linked to any specific reward. There is currently no research about which of these individual elements has the most impact on learners.

2.5 De-gamification

If gamification is adding game elements to a non-game activity, then de-gamification is the reverse: removing game elements, to reveal what the core activity is like. This is useful, because just adding game elements to sugarcoat a boring learning activity will not help – as Bruckman (1999) says this makes as little sense as "chocolate-dipped broccoli". De-gamification helps to see whether the core is "broccoli".

In developing the educational game concept for this project, I needed to come up with an idea, that would have an engaging core, such that either gamification elements should be so well integrated in the game idea, that they could not be removed without

altering the idea, or that the game should still be interesting when de-gamified, with all optional gamification elements removed.

2.6 Effectiveness in context

2.6.1 Specific target audience

In this project, my target audience is primary school children at the Piagetian concrete operational stage (7-11 years old). At this age, children have the necessary skills to learn vocabulary by reading and writing without much external help.

According to Ferreira et al. (2016) children in the pre-operational stage (2-7 years old) face difficulties when interacting with tablet devices, which would make a digital learning application less suitable for this age group.

Shin (2006) recommends that in teaching English to young learners (7-12 years old) educators should teach in themes, use visuals and realia (real-life objects), and involve students in making these visuals and realia. The game concept described in chapter 3. Game conceptualisation builds on these ideas.

2.6.2 Gamification context

Gamification is not the same as game-based learning (sometimes also called serious games or educational games). Plass et al. (2015, p.259) define game-based learning as "a type of game play with defined learning outcomes". Gamification can be implemented not only in games-based learning, but also in traditional learning activities in face-to-face or distance teaching. Khan Academy[1] is a popular example of a gamified platform, in which learners obtain points and badges from engaging with lessons, but it is not a digital game.

Plass et al. (2015) argue that it does not make sense to consider the effectiveness of gamification elements in general. This varies with different subjects and concrete learning activities, for example, "badges introduced into an MMO [massively multiplayer online game] may be useful to guide the learner to perform specific learning-related tasks, but when integrated in a casual game they may distract from learning".

This project falls under the umbrella of Digital Game-Based Language Learning (DGBLL) and focuses specifically on the application of gamification in a creative exploration vocabulary learning game.

2.7 Evaluation approaches

2.7.1 Aspects of evaluation

Many aspects of this project could be evaluated: the usability of the developed game (where usability is "the extent to which a product can be used by specified users to

[1] https://www.khanacademy.org/

achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (International Organization for Standardization, 1998)), the implementation time it requires in classrooms, and the pedagogical impact on learning outcomes and learner engagement as a whole or at the level of individual gamification elements.

Deferring the evaluation of pedagogical impact until after evaluation and improvement of usability and implementation time makes sense for 2 reasons: the first is that the effectiveness of impact on learning outcomes and engagement can only be reasonably measured over time, which makes them difficult to evaluate during the time-frame of an undergraduate project. And the second is that poor usability or difficulty of implementation could skew the results of other aspect evaluation. In a similar study, Schwabe and Göth (2005) developed a mobile game for students and decided to evaluate usability first and only then carry out pedagogical with the same reasoning.

Sim et al. (2006) conducted evaluations of 3 educational games with 25 children between 7 and 8 years old. They measured learning impact with pre- and post- tests, as well as observed and reported fun and usability, and found no correlation between fun and learning nor usability and learning. However, the participants only used each of the software products for 10 minutes between the two tests, which makes learning effects questionable at best – they could be skewed by lots of external factors and potentially short-lived.

2.7.2 Methods of usability evaluation

Usability testing of an application involves measuring how efficiently users can use it (is it easy to learn how to use it? Is it efficient to use once learned?), how effectively they can use it (how many errors do users encounter? How easily can they recover from errors?), and how satisfied they are with the design of the application (was there anything that was particularly good or bad?).

In the book "Interaction Design: Beyond Human-Computer Interaction", Sharp et al. (2019) write about different methods to test usability. The simplest approach is laboratory testing, where the application is tested in a controlled environment by users completing set tasks. This approach can be combined with evaluation of usability heuristics (see Nielsen (1994) for the most commonly used ones) to gain more design insights.

The author of "Mobile Design and Development" suggests that "the best way to ensure a usable mobile product is to test early, often, and in context" (Fling, 2009). Although laboratory testing is not as useful as field studies that are about observing users who try an application as they normally would, not in a controlled environment, but this year, field studies were difficult to carry out due to Covid-19 restrictions that required testing to be done remotely.

Like Sim et al. (2006), I decided to conduct evaluation studies measuring both observed and reported usability – observed by noting down participants' behaviours while they are completing tasks, and reported by participants in post-task semi-structured interviews.

Chapter 3

Game conceptualisation

3.1 Existing online gamified learning applications

3.1.1 Gamified language learning

The examples mentioned in the introduction – Duolingo, Memrise and Mondly are three current and successful gamified language learning apps. Duolingo is the most popular of these, with over 300 million users[1], while both Mondly and Memrise have over 50 million users each[2] [3].

Duolingo has a dedicated "Duolingo for schools" platform, which provides a dashboard view of students' progress for teachers, and allows them to set tasks for the students. Multiple studies have researched Duolingo's effectiveness: Rachels and Rockinson-Szapkiw (2017) conducted a 12-week pretest-posttest, non-equivalent control group study with 79 treatment group and 88 control group participants and showed that Duolingo's "Spanish for English speakers" course is as effective as face-to-face teaching for elementary school learners – there were no significant differences between both groups on two accounts – a 50 question vocabulary quiz and the Pattern of Adaptive Learning Scales' (PALS) Academic Efficacy subscale. In another study, Vesselinov and Grego (2012) collected data from 386 participants of different ages (but 73.5% were either in college or college graduates) over 8 weeks on the same "Spanish for English speakers" course and measured the level of improvement per hour according to the hours studied using Duolingo and WebCAPE Spanish test results at the beginning and end of the study – which showed that 84% learners improved their Spanish knowledge using Duolingo, although this was not compared to any other methods of learning. Notably, these studies focused only on English speakers learning Spanish and their findings may not generalise to learning other languages.

Memrise is not tailored for classroom activities, but offers the option for users to create their own courses or make learning lists from existing lessons, which teachers can use

[1] https://research.duolingo.com/
[2] https://www.mondly.com/support/appstore/en
[3] https://www.memrise.com/about

to set lesson plans for their students. This has been applied in practice, but without evidence about the outcomes (Memrise, 2013).

Mondly is unsuitable for classroom activities – its free features only allow users to take some starting vocabulary and daily lessons, and there is no customisation of content. However, there is a Mondly for Kids version of the application specifically made for children – neither Duolingo nor Memrise are tailored to target audiences of a particular age.

Below is a summary of the gamification elements that are included in Duolingo, Memrise, and Mondly for Kids. A complete table with screenshots can be found in the appendix (see Table A.1. Gamification elements in Duolingo, Memrise, and Mondly for Kids).

Gamification element	Duolingo	Memrise	Mondly for Kids
Points	Yes	Yes	Yes
Milestones	Yes	Yes	No
Leaderboards	Yes	Yes	No
Performance Graphs	Yes	No	Yes
Avatars	Yes	Yes	Yes
Teams	No	No	No
Virtual Currency	Yes	No	No
Side Narratives	No	No	No
Progress Bars	Yes	Yes	Yes
Levels	Yes	Yes	Yes
Encouragements	Yes	Yes	Yes
Winning Streaks	Yes	Yes	Yes
Personal Goals	Yes	Yes	Yes
Health Points	Yes	No	No

While these applications show many good examples of how gamification elements could be implemented, most of these are rewards that foster extrinsic motivation. None of them include any gamification elements related to teamwork and collaboration nor side narratives that help intrinsic motivation instead. In this project I decided to make a game that would have collaboration at its core, making it different to Duolingo, Memrise, Mondly for Kids.

3.1.2 Other online learning platforms

Khan Academy is one of the world's largest successful online learning platforms (with 90.4 million registered users at the end of 2019[4]). It covers multiple subjects, including mathematics, computer science, biology, chemistry, physics, and more. Khan Academy has integrated gamification elements, which include points, badges, levels, and personal goals (see Morrison and DiSalvo (2014) for an in-depth review). But there are few language learning resources on Khan Academy. Those that are imple-

[4] https://www.khanacademyannualreport.org/#free-education-for-anyone-anywhere

mented[5] focus on reading comprehension, which is unsuitable for very early beginners and young children who are just starting to read.

BBC Bitesize offers a greater selection of language learning resources[6] tailored for children of different ages (note that these resources are categorised into "levels", but this does not refer to the gamification element). These resources make use of the Side Narratives element through storytelling to help teach vocabulary.

3.2 The game idea

Players build a game world by writing words. In the beginning they begin with a blank, bare landscape, and add things to this world – hence the name "Fill in the World" (or "FITW" for short). For example, if they were playing in English they could add grass by writing "grass".

Each game item is internally called a "fitwick", which comes from the abbreviation FITW combined with a reference to Professor Flitwick from Harry Potter (who is a knowledgeable teacher). Players can click on any fitwick to see what its name is and also hear its pronunciation.

With multiplayer implemented, players can collaborate on worlds together, as well as explore existing worlds made by others, giving plenty of opportunities to discover new vocabulary.

3.3 Design for children

First and foremost, this game is made for children, so it must be appealing for them, otherwise all is for naught! I spoke to three primary school teachers and four parents of primary school-aged children about what children need for a game to be engaging. This includes:

- Good quality graphics to ensure that the game looks fun and appealing
- Music and sounds on interactions, to make it feel like the game responds to the children playing
- Game elements must not feel like sugarcoating on drill rota learning (which echoes section 2.5. De-gamification)

In retrospect, it would have been a good idea to involve children from the target age group in the requirements gathering process to make it designing *with* children rather than *for* children, as recommended by Druin (2002).

[5] https://www.khanacademy.org/ela
[6] https://www.bbc.co.uk/bitesize/levels/zf7hgwx

3.4 Educational elements

3.4.1 Language learning

The game concept easily lends itself to learning nouns and adjectives that are easy to visualise on screen, such as "orange bush" or "small house", or by sound, such as "wind" (since players can click on a game object and a sound related to it is played). Players would learn how to write, read, understand by listening and speak these words.

This is also not restricted to any particular language – simply providing multiple translations of fitwick strings and audio recordings would allow to play the game in any chosen language.

Further extensions to the game could include more complex language structures, such as phrases about objects in worlds. This would make use of semantic contingency (Rice, 1989), by building on known vocabulary in-context. Some ideas about how this could be achieved are included in section 7.4. Future extension ideas.

3.4.2 Learning theories

All game worlds in Fill In The World need to be populated with fitwicks. Beyond this, there is no predefined goal in the game. With full freedom of what players can do, they learn vocabulary through **pure discovery learning** (Mayer, 2004). This is good for fostering creativity, but as Mayer (2004) argues, it can detract from attainment of learning goals.

In a classroom or homeschooling setting, educators (teachers, parents or mentors) using Fill In The World should set specific tasks for their students. These tasks would restrict exploration to a particular topic or theme, for example "create 10 different desert-themed things in a desert world" or "explore a predefined farming world and learn the vocabulary used in it, which will be tested in a class spelling test". This instead then becomes **guided discovery learning** (Mayer, 2004), which is more effective. The use of badges works especially well in this context, since a teacher could create a badge that is awarded to students who complete their given task in-game.

Since the only way to add a fitwick is to type in its name (copy-pasting names is deliberately not implemented), players must remember the spelling of the fitwick they want to add. Whether this is achieved through asking another person (like a friend, parent or teacher) or remembering a fitwick they have seen in-game before, or just trying a word they know in real life, players use **spaced repetition** in coming up with words, which is an effective learning strategy (Roediger and Butler, 2011).

When players interact with each others' and shared worlds, they engage in **collaborative learning** (see Laal and Ghodsi (2012) for a review of the benefits of collaborative learning). Players learn new vocabulary from the fitwicks that others have added (which they can then use in their own worlds). At the same time, world creators get feedback and ideas from those who visit their worlds (and can use it to improve them). The entire process when players see what others have created, build something of their own, receive feedback, reflect and improve their worlds, and repeat is known as the

creative spiral (Resnick, 2008). It boosts intrinsic motivation to keep learning.

By varying the amount of support available for students, educators can adapt the game difficulty to the students' knowledge. This is aiming for the **zone of proximal development** (Vygotsky, 1980) and can improve how much learners get out of playing the game. For example, for young primary school-aged children who are not able to read or write yet, the game is still accessible with the help of someone who can type for them, as long as the children themselves come up with what to write. This can slowly transition into taking some of the scaffolding away (for example by letting the children type but helping them pick which letters they need). Some more ideas about adapting the accessibility of the game for different learners can be found in section 7.2. Extending game accessibility for different learners.

3.5 Gamification elements

All the gamification elements identified in section 2.4. Common gamification elements are compatible with the Fill In The World game idea, but only some were implemented:

- (Experience) Points [Implemented]
  - Adding items to the world could give players points. This is a reward directly linked to the players' actions. The amount of reward would be linked to their learning – once mastery of a topic is achieved, points would give diminishing returns to encourage learning new words instead
- Milestones (in the form of badges, trophies or achievements) [Implemented]
  - Badges could be awarded to players who reach certain milestones, such as "add 100 living creatures". In between milestones, progress to each one could be shown
- Leaderboards [Not implemented]
  - Teachers may give students the option to view comparative statistics of the class. This may show the number of things built in their game world (or even a finer breakdown, such as living creatures, buildings and nature). It could also work in conjunction with points and virtual currency
- Performance Graphs [Implemented]
  - Players' history of their own (experience) points, virtual currency, badges, or winning streaks could be viewed over time in graphs
- Personal avatars [Not implemented]
  - Players could be represented by an in-game character. This could even be made to resemble them in real life, if they took a photo of themselves and a cartoon-like caricature of them was generated from the photo
- Teams and teammates [Implemented]
  - Players could be allowed to build game worlds collaboratively. This does not have to be exclusive to the individual play option – multiple game world instances could be supported

- Side Narratives about activities and characters in the game, which don't relate to the player [Not implemented yet]
  - Different events could occur in the game, for example weather changes, natural disasters, visiting aliens, and similar things which would also be opportunities to learn new words in a particular topic
- Virtual currency [Not implemented]
  - Different structures or ecosystems could generate virtual currency. This is different from points, because the rewards are indirectly tied to the players' actions. For example, building a farm with cows and sheep could generate a stream of income over time, which players could spend on unlocking something new in the game
- Progress Bars and Levels [Not implemented]
  - Players' accumulation of points in the game could contribute to gaining levels, which would unlock something new. It would be most sensible for the game difficulty to increase as the levels progress, for example, more information about objects in the game could be displayed to players of a higher level
- Encouragements [Not implemented]
  - Audible cheering noises, confetti, or other congratulations could let players know when they have achieved a milestone, beat a personal goal, reached a new level, or simply gained some number of points
- Winning Streaks [Implemented]
  - Playing for consecutive days (or perhaps consecutive school days) could give players extra rewards, for example, a multiplier of virtual currency gained per hour
- Personal Goals [Partially implemented]
  - Players could set their own goals for the game, for example by designing their own badges, and monitoring progress towards these goals
- Health Points [Not implemented]
  - Players could have a fixed number of health points per day, which would decrease every time they made a typo, and prevent further play for that day if health reached 0

3.6 Parent-child play

Parents have a significant role in children's learning, especially during home school. Parent-child play promotes learning, emotional development, and communication (Hiniker et al., 2018). A game that allows mutual engagement by both parents and children greatly enhances its potential for greater learning impact.

The concept of "Fill In The World" includes collaboration at its core, which helps parents and children to engage in the role of teammates, without imbalance in their

roles. This allows shared ownership of created worlds. It is also interruptible at any time, as there are no time-limited features in the game.

3.7 Gotchas

There are a few gotchas in the game's conceptual design that may seem small but require careful attention as they are very important to the game usability:

- List of all fitwicks
  - It is not possible, given any realistic time and resource constraints, to include all dictionary words of a language in the game. It would also be extremely difficult to visualise some words graphically (imagine words like "moment" or "dedication"). Even though players may find implemented in-game words by seeing them in existing worlds, there is no way to know that a word is NOT implemented (and not that they might just be spelling it wrong). For this reason, there must be a list of all possible fitwicks in the game.
- Spelling suggestions
  - When a player mistypes a word, there must be some feedback given to them beyond just "Unrecognised Word". This is both to avoid frustration of players who do not know the correct spelling, but also to compensate for dialect differences (e.g. American vs British English with words like "license" and "licence").
- Multiple images for any fitwick
  - This gotcha was suggested by a parent. She told the story of an online interactive English quiz that her 7-year-old daughter had to do for homework – the child got stuck on an image of a pencil, because it looked so much like a pen. In Fill In The World, there are bound to be cultural differences in expectations of what things should look like, when aiming for a global audience. To compensate, multiple images must be available for any fitwick.
- Current real time
  - Children (and adults!) often do not realise how long they have been looking at a screen when playing. I included a clock that shows the current real time in the game as a reminder of time passing.

Chapter 4

Application design

4.1 Target Devices

4.1.1 App cross-compatibility

The devices used by the target audience are varied. Together with the switch to studying from home, many classroom activities have turned to mobile technologies instead, using personal smartphones. Most of these devices run on iOS and Android operating systems. Where classroom or blended learning is still possible, pupils can use school devices. Most schools in Scotland have desktop computers, and some have acquired Chromebooks and iPads.

To reach the widest possible audience, "Fill In The World" should be available for a range of low-end devices: desktops, laptops, tablets and smartphones. I decided to implement the game as a web application, so that it could run on virtually any device.

Developing for the web bypasses device incompatibility issues, however it can introduce new issues when internet connectivity is poor. This can be mitigated using a Progressive Web App – a web application that saves its data locally and works offline as well as online. The downside to developing specifically for the web is that this restricts use of native device functionality, for example, Bluetooth, GPS, or gyroscope sensors. I decided not to use any features that require such functionality in the game design.

4.1.2 Screen size adaptation

Due to limited time and resources on this project, I would not be able to optimise the game for all devices, so I had to choose at most 2-3 kinds of devices that the application should work best with. This was key to decide in the design phase, because I did not want to make multiple different designs for different devices. The main two things that differ with devices are the screen size (and therefore how the game should be displayed on screen) and the methods of interaction (touch, mouse, keyboard, movement sensors, etc.).

According to `statcounter GlobalStats`[1] data on internet users throughout 2020 (see Figure A.1), the most common screen resolutions are `1920x1080` (typical for laptops), `1366x768` (typical for tablets), and `360x640` (typical for smartphones). These are the three screen sizes I decided to optimise for. In designing for multiple kinds of devices at once, I chose to use Responsive Web Design with the Mobile-First approach – the game interface should fit on a mobile screen, but responsively scale to better accommodate larger screens.

4.1.3 Interaction compatibility

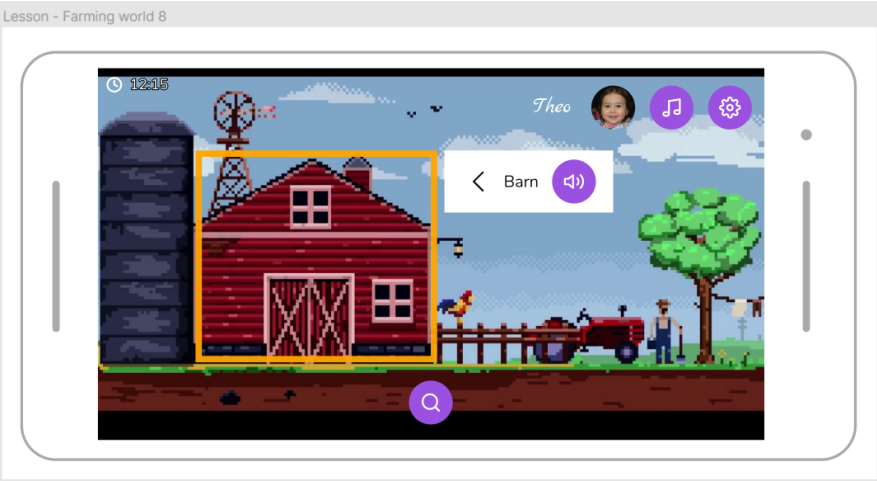
For best compatibility of interaction, I decided to make the game work with both mouse (or touchpad)/keyboard and touch/virtual keyboard interactions interchangeably. This can be done by deliberately avoiding interactions that are specific to physical interfaces (e.g. mouse right-click) or touch interfaces (e.g. two-finger swipe) or by implementing redundant equivalent interactions (e.g. controlling zoom with `CTRL` + mouse wheel scroll, or two-finger pinch in or out on a touchpad or a touchscreen).

4.2 Participatory design

I decided to involve teachers, parents, and children in multiple stages during the conceptualisation, design and implementation of Fill In The World.

The Covid-19 restrictions this year made testing in-context impossible, so I skipped creating paper prototypes, which don't work well with testing remotely. Instead, I started by creating an interactive wireframe mock-up using Figma that I could share online easily.

The full mock-up is available at https://www.figma.com/file/ICKHXQupyukvEkzhMuRn8P/App-Prototype?node-id=12%3A3 and here is a screenshot of one of the prototype screens:

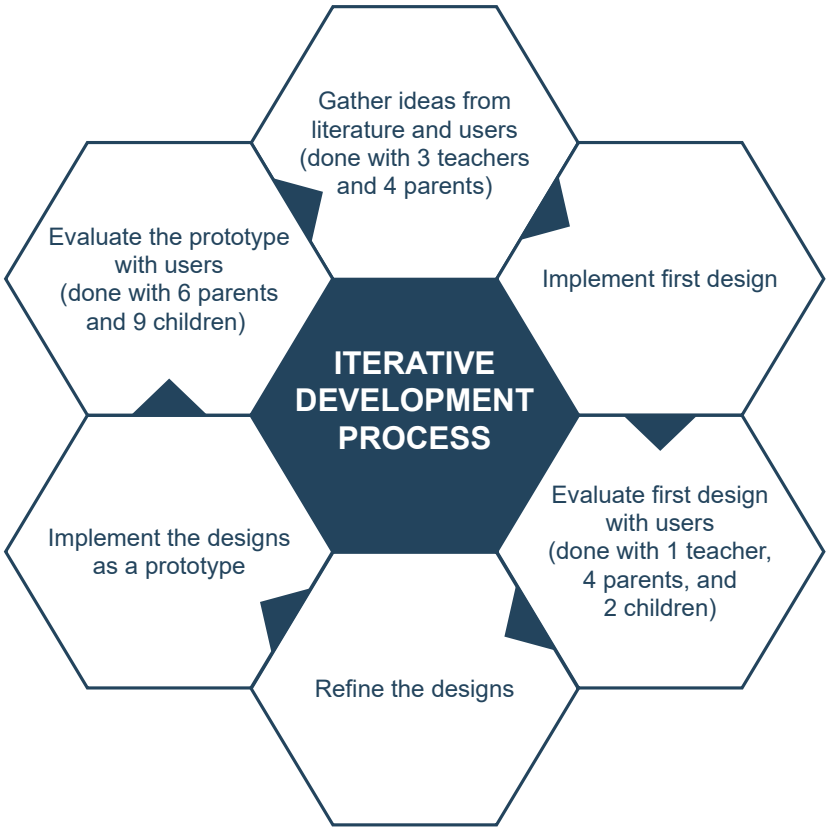


I then planned a formal interview study with parents and teachers to get feedback on the mock-up (see Appendix C. Interview evaluation study documents). It took a month

[1] https://gs.statcounter.com/

to get ethics approval for the study, so in the meantime, I focused on improving the design prototype and researching background literature.

Unfortunately, once the ethics approval was granted, I was unable to find participants willing to sign consent forms to take part in the official study. Instead, I ended up relying on informal feedback from 1 teacher and family friends: 4 parents, and 2 children.



The final stages of prototype implementation and evaluation with users are described in chapters 5. Implementation and 6. Evaluation and Discussion. Only one full iteration was carried out in this project, future extensions could follow the same cycle.

4.3 Design for appropriation

In the paper "Designing for appropriation", Dix (2007) lays out a design principle that is key to success of applications that could be used in many different contexts – they must enable user appropriation. Appropriation means that users can use the application in their own ways according to their needs.

The design of "Fill In The World" allows for appropriation by not setting any fixed storyline or goal that players must follow during gameplay – they are completely free to choose what they want to do.

4.4 First design iteration

The interactive design is much better explained visually than in plain text, so I recorded a short (<3min) video walkthrough that you can view here:

(Click on the thumbnail to see the walkthrough video on Media Hopper)

If you encounter any issues with viewing the linked media, you can try the offline versions included in the project materials archive. Otherwise, please contact me at s1750767@ed.ac.uk so I can help to resolve the issues.

See section 7.1. Fill In The World teacher companion app, which was also part of the initial design, but never implemented due to time constraints.

4.5 Further design iterations

With the received feedback, I revised the design to make it easier to use and evaluate. These are some examples of the design decisions that changed:

- I got rid of the groups feature, because groups would only be relevant to classroom evaluations that would have been difficult to organise remotely.
- Without groups, I simplified the main menu to show worlds straight away – there is no need to click buttons that lead to different menus anymore.
- The learning and creative modes were combined into one – the only significant difference between them is that learning worlds are not modifiable by students, and this is more simply achieved as a world setting instead.
- Practice mode was scrapped altogether – although useful for reinforcing learning, it was the least novel and exciting part of the game.
- I separated setting the game background and adding objects to the game. Making fitwicks like “sun” affect the background would be much more difficult to implement technically, and they would also mean that the same fitwicks would be necessary in every created world. This could get too repetitive and frustrating.
- I removed the undo button, because having reverse actions felt more integrated and flexible (e.g. deleting fitwicks to reverse adding, or changing background to reverse a background change).

Chapter 5

Implementation

You can see a walkthrough of how to use the implemented game prototype in this video:

(Click on the thumbnail to see the video walkthrough on Media Hopper)

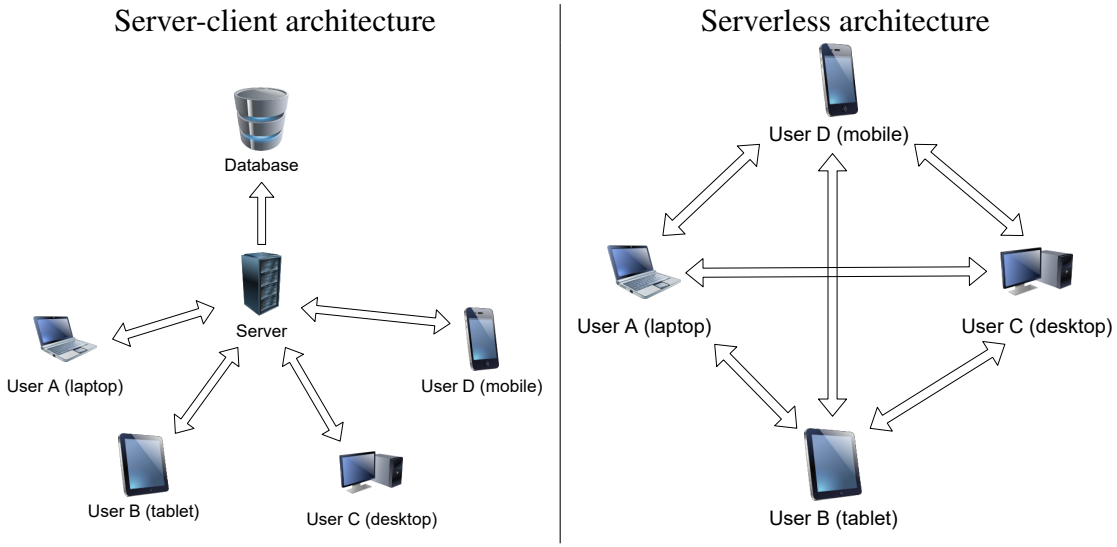
5.1 Architecture

To implement the game as a progressive web app that supports multiplayer (as discussed in section 4.1. Target Devices), two options are possible: a server-client architecture and a serverless architecture.

In the server-client architecture, there is one application (the client) that has all the front-facing functionality that users see, and another application (the server) that all clients communicate with. There is also a backend database, providing persistent storage for server data.

In the serverless approach, there is only one game application. All players' apps exchange data between each other every time something changes in the game, and the game state is distributed across all devices.

Here are diagrams that visualise both approaches (the arrows show which way communications can be initiated, i.e. “who talks to whom”):



The serverless architecture is more difficult to implement because it must be able to handle conflicting data coming from different users (for example, if one of the users lost internet connectivity and now has a different state of the world they were in than their peers). There is no single source of truth, unlike in the server-client architecture, where we can always trust the server’s game state if there is a mismatch. For the sake of simplicity and robustness, I decided to use the server-client architecture in this project.

5.2 Client application

The full source code for the client application be found at https://github.com/Vidminas/fitw-client. Altogether, it contains 5256 lines of source code (92% is TypeScript, 7.5% is CSS, and 0.5% is HTML).

5.2.1 Front-end framework

Cross-platform responsive web design can be made easier by building on a front-end framework. Such frameworks provide helper components that work well on different devices (for example, a card component that appears in the native style of Android or iOS depending on what device is used to access the page). Furthermore, most frameworks also offer the possibility to build a hybrid application (that can use native device features like Bluetooth) in the future, if needed.

I considered multiple options according to these criteria: which platforms the framework supports, what languages they integrate with, and licensing:

Framework	Supported platforms	Language/framework integrations	License
React Native[1]	Android, iOS, (Web, Windows, MacOS, Linux)[7]	HTML/CSS/JS, React	MIT
Xamarin[2]	Android, iOS, MacOS, Windows, (Web, Linux)[7]	C#/.NET	MIT
Flutter[3]	Android, iOS, Linux, Web, (Windows)[8]	Dart	BSD 3-Clause
Ionic[4]	Android, iOS, MacOS, Windows, Web	HTML/CSS/JS, React, Vue, Angular	MIT
Qt[5]	Android, iOS, Windows, Linux, MacOS	Python, C++, QML	Qt license
Unity[6]	Android, iOS, Windows, Linux, MacOS	C#/.NET	Unity license

Table 5.1: Cross-platform framework comparison

To have more flexibility in how this app could be deployed in the future, I decided not to use Qt or Unity, which have more restrictive licensing than the other frameworks. Qt and Unity licensing could interfere with my ability to make the project fully open-source and if this app were to ever make money, Qt and Unity would require part of the revenue.

Then, I eliminated Xamarin, which has only unofficial support for the web, and Flutter, of which many features are still in alpha stages. Another reason to eliminate Xamarin and Flutter is that I am more confident programming in JavaScript and React than C# or Dart.

Finally, between React Native and Ionic, I picked Ionic, because it supports more platforms out of the box and has full official support for progressive web apps. Ionic also requires less effort to implement an app that works everywhere with the same code ("write once, run anywhere" philosophy) compared to React Native's approach, which is separate code for each device/platform written in a common language ("learn once, write anywhere" philosophy).

[1] https://reactnative.dev/
[2] https://dotnet.microsoft.com/apps/xamarin
[3] https://flutter.dev/
[4] https://ionicframework.com/docs
[5] https://www.qt.io/
[6] https://unity.com/
[7] Additional support provided by community-contributed extensions
[8] Support in alpha stage

5.2.2 Game engine

Although Ionic is good for creating cross-platform web apps that can also be easily made into hybrid apps with only a single codebase, it has no built-in features for building games. Here, a game engine would be very helpful to handle needed functionality, such as loading images and audio, playing sound, handling input events and camera view of the game world.

I picked a popular game engine called Phaser 3[7] for 3 reasons: because it is actively being developed and maintained, meaning it works with up-to-date browser versions, because it is popular, meaning lots of documentation, Q&A sites, and tutorials are available on the internet, that make it easier to get started, and because it is licensed under the MIT license.

Integrating Phaser and Ionic took me a long time because all tutorials that did this were out-of-date and I was completely new to both frameworks. Once I figured out the setup, the functionality both frameworks provided made up tenfold for the time lost.

5.2.3 User authentication

When players open the game for the first time, they are asked to log in with a registered email address. There are two main reasons for this: user portability and server-side logging.

User portability means that players who sign in on one device (e.g. their laptop), can also log in with the same user on another device (e.g. their smartphone) simply by logging in with the same email address. This also allows player to re-login with the same user on a device after clearing their browser data. With only a few lines of additional code to create a "log out" button that clears site data, this mechanism allows multiple users on the same device too!

Server-side logging is about the pseudonymous logs of player interactions that are collected by the game. These logs are used for debugging (they allow to see what happened leading up to an error, and sometimes, a whole error stack trace too) and for evaluating features (for example, if there are 4 players in a new world, and no one has changed the background, perhaps the "change background" button is not visible enough). User authentication helps to keep this collected data to a minimum, reduce load on the hosting server, and open up to fewer security risks by not allowing random internet users to access the game.

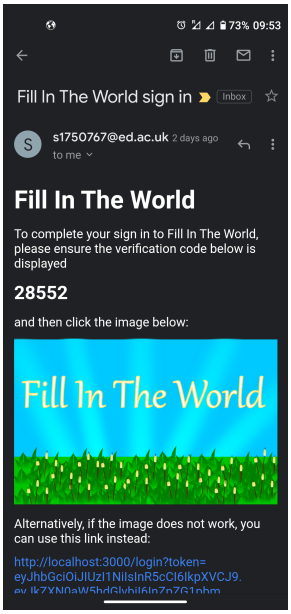
There is a whole area of research about making usable user authentication for children. Since this is not my project focus, I decided to not delve into it too far, and this feature could definitely be improved in the future (see section 7.5. Usable security for children).

One of the simplest and most widely used user authentication approaches is an email and password login form. However, this requires users to remember both the email

[7] https://www.phaser.io/phaser3

they signed up with, and their password, which can be difficult, so I tried to make the sign in process easier by getting rid of passwords altogether.

Instead, users enter only their email address in the login form, and they receive a "magic link" in their inbox – a special link that only works for a short amount of time allows them to log in. To make it look more friendly, I included an image banner and a verification code appears both in the game website and the email to help avoid confusion if multiple emails get sent. This is what the email looks like on a phone:



5.2.4 Game assets

Game assets are all the files included with the game that are not code, like music, voice recordings, graphics, and configuration files.

Fill In The World needs *a lot* of music and graphics assets, far more than typical browser games, because it needs to have assets for every fitwick, and in theory, there can be as many fitwicks as there are words in a language. There was no way that I could create all these assets myself, so instead, I turned to public domain and creative commons licensed resources available on the internet. The websites I used are:

- https://pzuh.itch.io/free-game-gui
- https://tokegameart.net/category/freebies/
- https://opengameart.org/
- https://craftpix.net/freebies/
- https://www.gameart2d.com/freebies.html
- https://kenney.nl/assets
- https://openclipart.org/
- https://www.freepik.com/vectors/

There are 298 possible fitwick sprites for 167 unique fitwicks in the game.

The game music is licensed to me after purchase from the Humble Bundle[8] (and hence not available in the game repository unlike all the other assets).

All the voice recordings are my own, recorded and edited using Audacity[9]. There are 35 fitwick pronunciation recordings.

All the fitwick names in the game are linked to corresponding images and voice audio in a JSON configuration file, which could be easily extended by anyone with some technical knowledge to include more fitwicks in the game.

The full list of assets with their sources and respective licensing information can be found in the source code repository and in-game (in the main menu book, click on the credits button in the top-right).

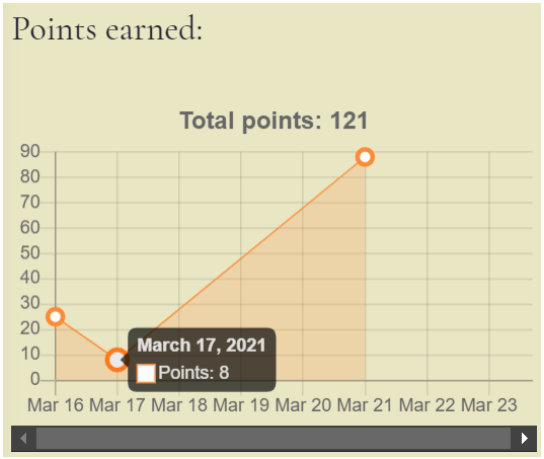
5.2.5 Implemented gamification elements

The Fill In The World prototype implementation includes 6 gamification elements: **points, performance graphs, winning streaks, badges, personal goals, and teams**:

- Points
  - Adding fitwicks to a game world gives players points. This is a reward directly linked to the players' actions. The amount of earned points gives diminishing returns for the same fitwick using a simple decay function:

$$points = 10/(1 + \#timesFitwickWasCreated)$$

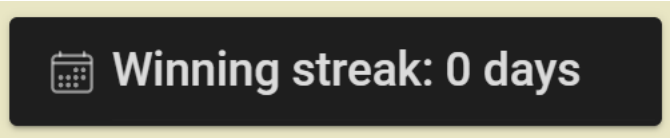
    (which means that the first time a fitwick is created, this gives 5 points, 2-6 of the same fitwick give between 5 and 2 points, 7-20 fitwicks give 1 point, 21+ give no points). This encourages players to learn a variety of different vocabulary instead of adding the same fitwick over and over again.
- Performance graphs
  - The performance graph shows a player's history of their earned points day-by-day. Here is a screenshot with my player data:



[8] https://www.humblebundle.com/
[9] https://www.audacityteam.org/

This graph helps to visualise progress over time.

- Winning streaks
  - Playing for multiple consecutive days earns players a winning streak (this could easily be configured to be consecutive school days instead). In the prototype, the winning streak is shown by an indicator next to the performance graph (which helps to see when a winning streak began or when it may have been lost):



- Badges
  - Badges are awarded to players who reach certain milestones, such as the tree badge described in the screenshot below:

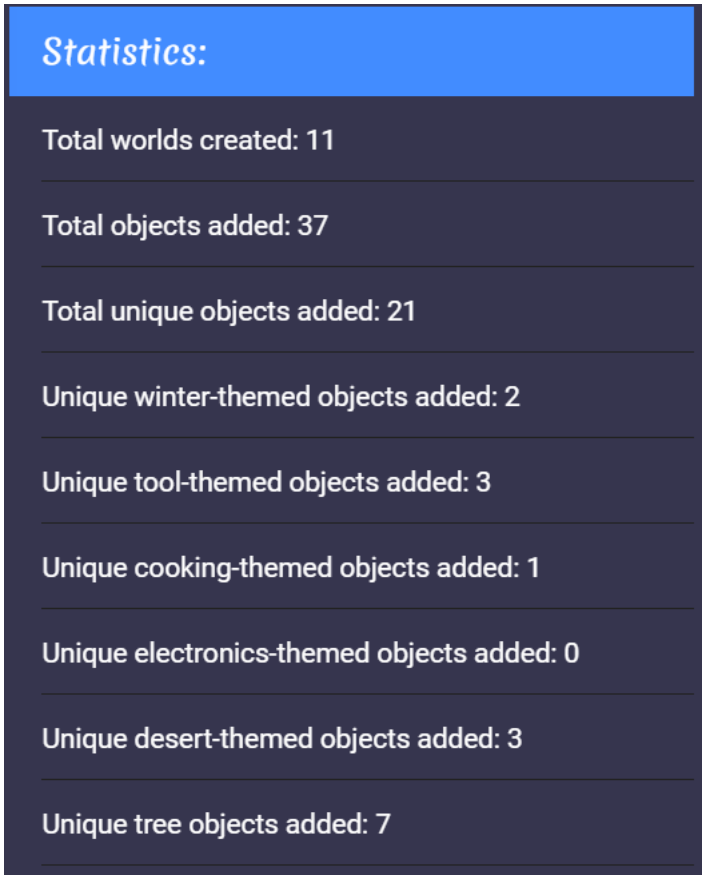
When a badge is not yet achieved, clicking on it shows a popup message with the player's progress towards earning it, such as "You don't have the Pyramid badge yet, 2 objects to go!"

The amount of fitwicks needed to receive each badge depends on how many different game assets I managed to find and include. The Electronics badge, for example, needs 10 different electronics fitwicks to be placed, while there are 19 fitwicks categorised as electronics in the game. This makes it a relatively easy badge to obtain, as there is a lot of choice.

The Toolbox badge is the most difficult badge to get – it needs 20 different tools to be placed, and there are exactly 20 different available tools in the game.

- Personal goals
  - As there is no clear way to "win" in this game, players have no choice but to set their own personal goals (which could be to earn all the badges, beat a friend's point score, or simply build a really cool world!). This

fosters creativity and imagination. Statistics that are open to the players' interpretation are accessible to help own goals:



- Teams and teammates
  - Players can build game worlds collaboratively in real-time or individually, because all world data is synchronised with the game server. This allows sharing of creative ideas and exchange of knowledge, and increases intrinsic motivation to keep playing.

More gamification elements could be included if the game was developed further, and some ideas can be found in section 7.3. Unused gamification elements.

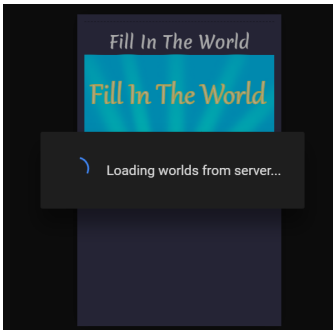
5.2.6 Performance optimisation

As Fill In The World requires many game assets and exchanges data with the server over the network, this has an impact on the runtime performance of the game.

I did not focus on optimising performance of the game, because very well optimised code is often device-specific (which means more code to write) and generally takes longer to write. This code quickly becomes obsolete as features change – the game is only an early prototype after all – which is wasted effort. Instead, performance optimisation would become an important task when making a production-ready application after multiple prototype iterations.

Where waiting could not be avoided, I used progress indicators in the game interface

– such as loading spinners while waiting for a response from the server or a progress bar while the game assets are loading as shown in the screenshots below:



This is a tactic proven to reduce the negative psychological impact that waiting has on users (Myers, 1985).

5.2.7 Testing

Although web apps run without much extra effort on different devices, platforms, and browsers, there are no guarantees that they will look consistent. In fact, they shouldn't – for example, buttons on a phone screen should be much bigger relative to the rest of the user interface than on a laptop screen.

I do not own all the different devices that users are most likely to be using: laptops running Windows, Mac and Linux, or iPads and Android tablets, or iPhones, or Android or Windows smartphones. Therefore, to test my game without spending lots of money or bothering lots of people asking them to help, I found a testing platform called BrowserStack[10].

BrowserStack allows to virtually run my game on any of these devices from my laptop. It helped me find and fix bugs that only showed up with Safari on an iPad. Normally this service is paid, but I got a free subscription using their open-source project support scheme after making my code available under the MIT license.

5.3 Server application and database

The full source code for the server application be found at https://github.com/Vidminas/fitw-server. Altogether, it contains 2036 lines of source code (84.5% is TypeScript, 11.5% is Handlebars HTML, and 4% is JavaScript).

5.3.1 Back-end framework

When planning the server application, my main requirement was to be able to use the same programming language as for the client application. Having never done full-stack programming before, learning multiple new frameworks very quickly was challenging enough without having to learn multiple languages too. This is why I chose

[10] https://www.browserstack.com/

the Node.js[11] runtime to build the back-end.

There are multiple Node.js web server frameworks available, but by far the most popular one in 2020/21 is Express.js[12][13]. Using this framework, I built a small HTTP API that the client could use to retrieve data about game users and worlds.

5.3.2 WebSocket communications

The HTTP API is good for typical server-client data exchanges. The client sends a request to the server and the server returns a response. This is used in the client /home page to retrieve data about a player's name, badges, statistics, and worlds.

However, to support live multiplayer in Fill In The World, the server must be able to initiate communication with the client too, to inform them about game state changes caused by other clients. The HTTP API does not support this. To allow this two-way communication between the server and every client, I used WebSockets (and specifically, the socket.io[14] that simplifies the use of the WebSocket API) when the client /game page is opened.

5.3.3 Database

While at least one player is connected to a game world, the state of that world is saved in the memory of the server and modified every time the client alerts the server of a change. Similarly, while a player is connected to at least one world, their user data is also held in memory.

When all players disconnect from a world, world data is saved to persistent storage in a database. Similarly, when a player disconnects from all worlds, the player data is also saved to the database and cleared from server memory. This helps to conserve resources and avoid loss of data (for example, if the server crashes) because the database is backed up twice daily and saved in redundant locations.

Initially, I started using a MySQL[15] database, because I already had previous experience with it. However, after writing almost 100 lines of code in the server application just to connect to the database and check its integrity, I realised this approach would not work well at the scale that the entire game requires. This is why I switched to MongoDB[16] (advertised as "the most popular database for modern apps"). With the help of the mongoose[17] library (which simplifies using MongoDB specifically for Node.js apps), far less boilerplate code was required to integrate the new database with the server, and I could spend more time on developing game functionality instead.

[11] https://nodejs.org/en/
[12] https://expressjs.com/
[13] You can verify this with the number of GitHub stars the Express.js repository has compared to alternatives. A concise summary of links and statistics can be found at http://nodeframework.com/
[14] https://socket.io/
[15] https://www.mysql.com/
[16] https://www.mongodb.com/
[17] https://mongoosejs.com/

5.3.4 Logging and secret admin panel

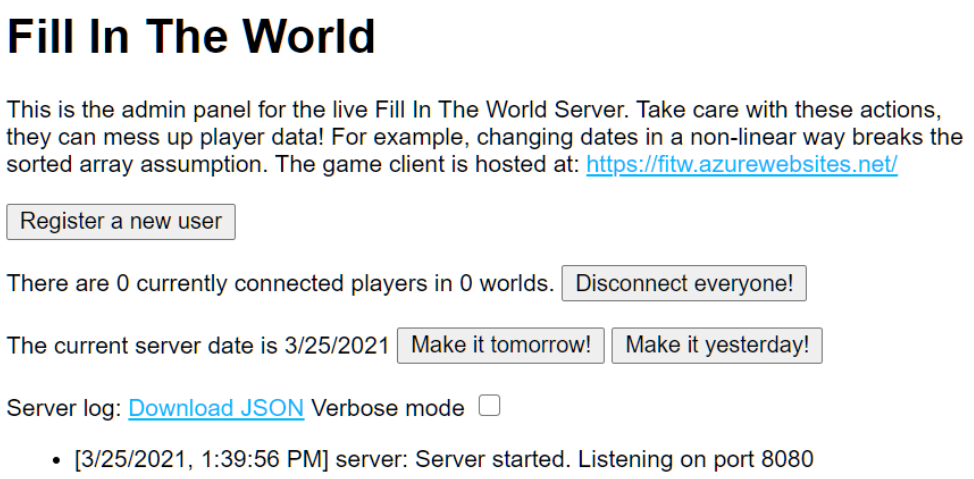
As explained in subsection 5.2.3. User authentication, the server maintains logs of client activity to help with debugging and evaluation.

The logs can be viewed at the server application's `/fitwick` page which contains the admin panel. There are no links to this page, and search indexing of the live server sitemap is disabled, so it is a "secret" panel of sorts, although anyone who knows the link can access it. In a real application, I would take the security of this feature much more seriously and only allow authorised IP addresses to access the page.

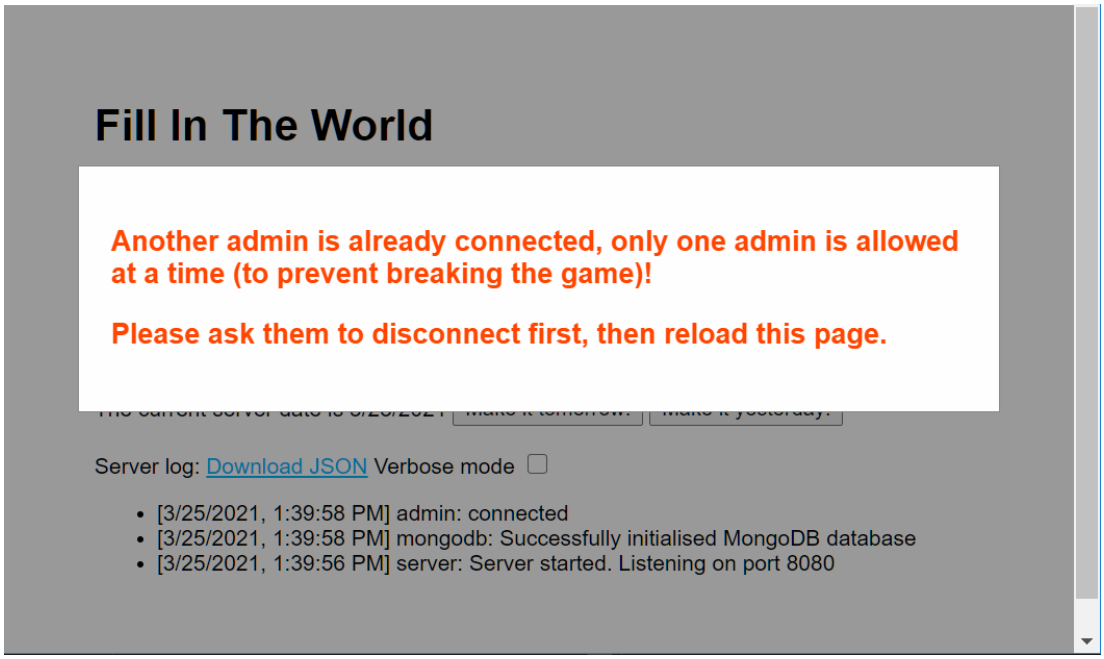
An example extract of server logs is included in Table A.2.

In addition to viewing logs, the admin panel has some useful features: logs can be downloaded locally in JSON format, the admin can see how many players and worlds are currently live (in server memory), there is a button to disconnect everyone and save all data (in case a bug keeps a player or world live permanently) and a form to register new user emails. There are also buttons to change what date the server considers to be today, which helps to test the winning streak feature in one day.

Here is a screenshot of what it looks like:



To protect the game state, only one person can access the admin panel at a time. If another person attempts to open it (which also applies if the same user opens the panel in two different browser tabs), they are presented with the following message instead:



The server is not using any front-end framework. The admin panel page is implemented with the very lightweight HTML view generator `Handlebars.js`[18] and `socket.io` with vanilla JavaScript handle live data updates.

5.3.5 Server-side user authentication

The user-facing authentication process is described in subsection 5.2.3. User authentication, but there is more to it than just entering an email address in a login form.

When an email address is entered in the login form, a POST HTTPS request is sent to the server. The server then verifies the email address using the `Passport.js`[19] authentication library with the `passport-magic-login`[20] strategy. The strategy consists of 2 steps:

1. The server generates a temporary access token and sends the email that the users see to the submitted email address (I used `SendGrid`[21] to deliver these emails).
2. When the user opens the link with the access token, this sends another HTTPS POST request to the server, letting it know that this is the genuine owner of the email address. The server responds with a unique user ID associated with the email address if there is one or an error if the email address is not registered.

This approach delegates authentication to the users' email service provider instead of my server application, and I only have to handle authorisation in the second step.

To protect personal data, user email addresses are hashed on the server side using `bcrypt`[22] – a secure hashing algorithm meant for passwords, and never stored in

[18] https://handlebarsjs.com/
[19] http://www.passportjs.org/
[20] https://github.com/mxstbr/passport-magic-login
[21] https://sendgrid.com/
[22] https://en.wikipedia.org/wiki/Bcrypt

plaintext. Instead, when a user opens a temporary access token link (from step 2 of the `passport-magic-login` strategy), the server searches through all stored email hashes in the user database and looks for a match. This is an approach that I came up with myself and it ensures that only securely hashed and salted user data is stored.

5.4 Live deployment and data protection

The live client application can be accessed at https://fitw.azurewebsites.net/.

The live server application can be accessed at https://fitw-server.azurewebsites.net/.

Both applications are deployed on Microsoft Azure Web App service[23] Linux containers. The backing server database runs on Azure CosmosDB[24].

The entire setup is completely free – using the lowest tier Web App service and CosmosDB resources does not cost anything on Azure. This heavily impacts performance and upgrading to a paid subscription could be a quick way to optimise the game as one of the potential solutions to the problems mentioned in subsection 5.2.6. Performance optimisation.

I chose to use Azure, and not Google Cloud[25], Amazon Web Services[26], or another hosting service, although most of these platforms also offer free resources (or alternatively, free temporary credit for students). This is because Microsoft Azure has better compliance features – I could restrict all data transfers to be within the UK South and UK West regions, to comply with GDPR legislation. This is important, because even though Fill In The World only stores hashes of user emails, according to GDPR, this is still considered pseudonymous personal data and must be appropriately handled.

As per my data management plan, attached in the appendix Appendix D. Usability evaluation study documents, I will delete all stored user data by 01 June 2021 for full GDPR compliance.

[23] https://azure.microsoft.com/en-gb/services/app-service/web/
[24] https://azure.microsoft.com/en-gb/services/cosmos-db/
[25] https://cloud.google.com/
[26] https://aws.amazon.com/

Chapter 6

Evaluation and Discussion

6.1 Planning usability evaluation

6.1.1 Initial study plan

I chose to collect data about user satisfaction (based on recalled good and bad features, as well as expressions of frustration or satisfaction), learnability (based on what features users figured out without explanation), efficiency (based on how quickly users could perform common tasks and whether they were satisfied with the User Experience (UX)), and risk (based on errors encountered), in line with subsection 2.7.2. Methods of usability evaluation.

To help with technical debugging, I also saved server logs about user interactions with the game after every study (except the last one – see Appendix B. Usability evaluation results for details).

The study was designed to include a few tasks that children could complete (with the help of a parent as needed), and then answer some questions. To avoid tiring out the children, as recommended by Hanna et al. (1997), the whole process was planned to take 30 minutes.

6.1.2 Pilot studies

After finishing the first game prototype, but before running official evaluation studies, I conducted 3 unofficial evaluation sessions with my younger siblings. Another recommendation from Hanna et al. (1997) is to not conduct studies with own children, because they may be inclined to not be honest in their feedback, which is why I did not include them in official evaluations, only the pilot sessions.

These pilot sessions helped to catch some flaws in the study plan. For example, I changed the task of getting the Toolbox Badge, which requires placing 20 tools, to obtaining the Tree Badge instead, which requires placing only 5 trees, because it would take children too long to place 20 objects. They also helped to spot and fix some usability issues, for example, the long-press delay of 251ms felt too long and clunky

on tablets, so I reduced it to 150ms.

The finalised study protocol can be found at the end of Appendix D. Usability evaluation study documents.

6.2 Usability evaluation

6.2.1 Participants

After the pilot studies, I conducted 5 official usability evaluation studies with 9 children (aged 6-13) and 6 parents altogether.

All the participants were Lithuanian native speakers, learning English as a 2nd or 3rd language. I translated all the study documents to Lithuanian to ensure that all the parents and children could clearly understand the purpose of the user study and what they are consenting to by participating.

6.2.2 Methodology

During each of the studies, children had to complete a few tasks: open the game, get familiar with the controls by interacting with a pre-created world, and then create their own world and obtain the Tree Badge by placing tree fitwicks in this new world. Their parents could join in, helping the children as needed, especially the younger ones.

During the tasks, I gathered notes about my observations of children's and parents' interactions with the game, and their questions and comments to gain insights into observed usability and enjoyment. To analyse these notes, I used coding of the types of good and bad features encountered, and observations about user satisfaction.

After completing all the tasks, I asked the children some questions in a semi-structured interview style to get their reported usability and enjoyment of the game.

6.2.3 Results

The full notes and codes can be found in Appendix B. Usability evaluation results.

The observed usability notes uncovered loads of usability issues (30 individual coded issues in the 5 studies), mostly related to performance problems and graphical bugs. I highlighted the most important problems as "**critical**", and 4 out of 5 studies were disrupted by critical problems.

After conducting the studies, I managed to implement bug fixes and improvements for all the discovered critical issues and the majority of the lesser ones. The collected server logs helped to identify what happened leading up to the issues and some included actual browser error details, which were very helpful.

A common critical problem was the long loading time of the game. As discussed in subsection 5.2.6. Performance optimisation, this was not my development focus, but

it turned out to be more relevant than I had considered, so I implemented performance optimisations using lazy loading[1] and object pooling[2] techniques.

There were multiple device compatibility issues with the Samsung Galaxy Tab 2 tablet. For now, my recommendation is to use a different device, because I could not reproduce these issues myself and thus fix them.

On the other aspects of usability – the learnability of the game was great, all 9 participants managed to figure out how to use the game by themselves or with limited help, even though there is no tutorial in the game.

All the participants managed to recover from their errors (none of their actions led to the game being in a broken state).

The effectiveness of use was mediocre, and multiple suggestions for improving this were made, most notably, the moving of fitwick confirm/delete buttons next the to the fitwick that is held up.

The observed satisfaction of users was good, except in cases where critical problems prevented them from playing the game. 7 of 9 participants reported that they enjoyed the game, while 3 also made comments about things they did not like.

6.3 Evaluation of implemented gamification elements

The final game prototype included points, performance graphs, winning streaks, badges, personal goals and teams (see subsection 5.2.5. Implemented gamification elements).

Analysing from the degamification perspective (see section 2.5), personal goals and teams are embedded in the game idea, but points, performance graphs, winning streaks, and badges are just layers on top. A way to see this is to consider *when* these gamification elements are relevant to the gameplay. Personal goals and teams are always relevant, no matter what screen the player is on (`/home` or `/game`), and taking them away would change the game. On the other hand, performance graphs, winning streaks, points, and badges dominate the `/home` page, but are not integrated at all with the `/game` screen, making them less valuable.

The children who evaluated the game partially agreed with this valuation – all 9 participants found the multiplayer exciting (if they were evaluating alone, I joined them in-game from my laptop). 7 of 9 participants mentioned the freedom to choose what to do in the game when asked about what they liked in the game, which links to personal goals.

Besides multiplayer and personal goals, badges seemed to be worth more than the rest of the elements. This may be because of the way I structured the usability study – one of the tasks was to find the Tree Badge, which we would try to obtain during the session, but there were no tasks about the performance graph or winning streak. I chose this study design, because there is nothing to see about points when a player has just

[1] https://blog.ourcade.co/posts/2020/phaser3-load-images-dynamically/
[2] https://blog.ourcade.co/posts/2020/phaser-3-optimization-object-pool-class/

logged in for the first time, but they can interact with badges and read what is required to obtain them.

6.4 Research outcomes

The main goal of this project was to design, develop, and evaluate the usability of an educational game for learning vocabulary. This was successfully achieved with a complete prototype of "Fill In The World".

The secondary research question in this project was "would a game like Fill In The World be viable for a future study about the effectiveness of individual gamification elements?"

The answer is yes – Fill In The World has lots of strengths that can be capitalised on and weaknesses that can be overcome:

- Although the game is not easy to implement on a larger scale (and extending the game would worsen performance which already had an impact in the first prototype), these are just technical issues that are possible to overcome, not hard barriers.
- Conceptually, the game idea is very flexible and is compatible with all the gamification elements that were identified in section 2.4. Common gamification elements. For concrete ideas about how they could be implemented, see section 7.3. Unused gamification elements.
- The usability studies verified the game core as one that is fun to play. After fixing all the usability issues, the game should be fun to play, and thus be useful for gathering results about effectiveness of the game elements.

In extending the project further, the most useful approach would be to continuously involve children, parents, and teachers in participatory design.

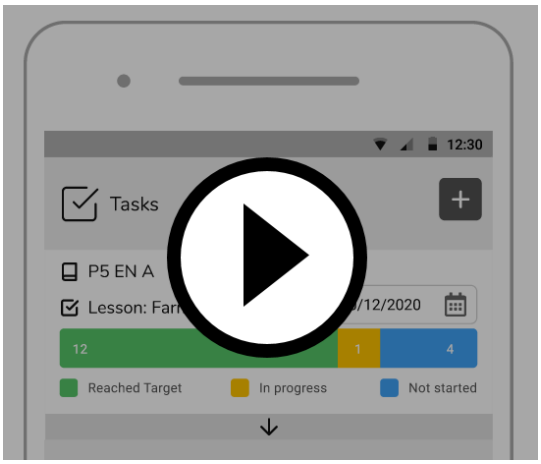
Chapter 7

Reflection and Further Work

7.1 Fill In The World teacher companion app

A companion app for teachers to set tasks and monitor student progress was also part of the initial design. It was never implemented due to time constraints, but it would be the most useful future extension of the suggestions in this chapter.

Here is a video walkthrough of the prototype designs for the teacher companion app:



(Click on the thumbnail to see the video walkthrough on Media Hopper)

Using the companion app, teachers could set tasks for students ranging from very general like “add 10 new things to your world”, to very specific like “achieve mastery of all words from a given list of household items”. These tasks could be represented in-game as badges.

This companion app would tackle the problem explained in the introduction – that teachers have less information about their pupils in remote than in face-to-face learning. Providing live statistics about students’ interactions with the game and flagging up pupil inactivity or common mistakes to teachers would aid teachers in helping their pupils learn better.

7.2 Extending game accessibility for different learners

7.2.1 Physical gestures

The game idea is inherently only partially useful for deaf and completely unsuitable for blind children.

With high-contrast adaptation, the game can be made to work for limited vision users, however it is completely unsuitable for blind children. One of the unused concepts in this project from Shin's (2006) recommendations for teaching English to young learners is to teach using movement and gestures, which could help to physically embody concepts. The addition of game mechanics that make use of physical movement could also increase the accessibility of "Fill In The World". There are existing games for young children's literacy learning through physical activities on the Xbox Kinect, described by Homer et al. (2014).

7.2.2 Other input methods

Very young learners who cannot yet read and write on their own cannot use the game by themselves. Alternative input methods could help to make the game more accessible. Read et al. (2001) conducted a study evaluating the usability of four different input methods with children aged 6-12: mouse, keyboard, speech recognition, and handwriting recognition, which suggests that speech recognition and handwriting could be valuable alternative input methods – although they were slower, the user satisfaction was higher.

Drawing recognition, for example with Google's AutoDraw[1], is a new input method alternative that could be very useful for young children who could draw objects and hear their names pronounced, without needing to know how to read or write.

7.3 Unused gamification elements

As detailed in section 3.5. Gamification elements, the elements that were not implemented are: Leaderboards, Personal Avatars, Side Narratives, Virtual Currency, Progress Bars and Levels, Encouragements, and Health Points.

Developing the game further, virtual currency would be an easy and interesting extension to add. It could easily replace the current points system, but also give meaning to earning points – instead of just setting highscores, players could gather virtual currency for purchasing in-game goods. Virtual goods for purchase could be world backgrounds, winning streak freezes (like in Duolingo, when a player has a winning streak freeze, it gets used up instead of losing the streak when that player misses a day), or abilities that facilitate world building (for example, multi-construction: the ability to build a house with a garden with a single word, instead of having to add many fitwicks one-by-one).

[1] https://www.autodraw.com/

Side narratives would be the most promising intrinsic motivation boosting element to add, although the addition of this would be much trickier.

7.4 Future extension ideas

In the application mock-up design, I came up with 2 modes of play: “creative” mode allows creating new worlds or exploring and adding to existing ones, and “lesson” mode helps to review and reinforce learned vocabulary. The “lesson” mode was never implemented, since it is not as novel and open-ended as “creative” mode – yet it would be useful for a more learning-oriented (rather than exploration-oriented) application like Duolingo, Memrise or Mondly for Kids.

In the current “Fill In The World” prototype, players can create separate worlds for different themes of different granularity. For example, they can make a large-scale world to show a castle with a nearby village, with trees, houses, and plants, and a small-scale world to show the inside of a house. However, it would be interesting if worlds could be linked, such that it were possible to enter the inside of a house by clicking on it outside, or exit from the interior to go back outside.

For more advanced learners, this game could be expanded to include phrases about objects and conversations between in-game characters. For example, players may be able to scope to a game world object and see some phrases about its material or location (as shown in the Figma designs) or even interact with a game character and ask them some questions (or get asked some in return).

More languages could easily be added to the game, because the fitwick data is not hardcoded – it would simply require writing additional configuration files. The most complex part would be adapting any other input methods, such as speech recognition or handwriting recognition to multiple languages, if these were added too.

7.5 Usable security for children

Email passwordless authentication implemented in this project is already a step ahead from traditional username-password authentication, as it does not require children or parents to remember any secret code, only what their email address is. However, authentication systems more suitable for children exist, for example, Hundlani et al. (2017) describe parent-child authentication mechanism, in which parents can approve their children’s passwordless logins using a mobile device. Graphical passwords are likely not a good alternative, because according to a study with 13 children aged 6-12 by Cole et al. (2017), the children were even less likely to remember graphical passwords than textual ones.

7.6 Personalised learning

7.6.1 Adaptive difficulty

Currently the game is exactly the same for anyone who uses it. The inclusion of multiple badges that are of varying levels of difficulty helps to balance out learner differences (as the easiest badges should be possible for anyone to obtain), but more could be done to support this.

Shute et al. (2019) point out that well designed games should include challenges that adapt to the learners' skill levels. This could be achieved by implementing levels and increasing the complexity of vocabulary or phrases that the game shows to the players.

7.6.2 Personalised gamification

Even when gamified learning activities are implemented, they only target a specific audience of learners (Dicheva et al., 2015). This leads to the natural conclusion, that there is no "one size fits all" approach to gamification implementations.

Teachers are best suited to determine what works (or does not work) well for individual students. Allowing teachers to adapt the gamification implementation for each student – an adaptive or personalised gamified learning approach – may improve learner engagement, satisfaction, and learning outcomes.

Allowing teachers to apply gamification elements of their choice in learning activities by toggling them on or off would enable the adaptation of activities to individual students' needs and preferences.

Collecting data about learners' interactions and engagement and summarising them in a user-friendly dashboard in the teacher companion app would also help teachers to track individual students' progress.

7.7 Conclusions

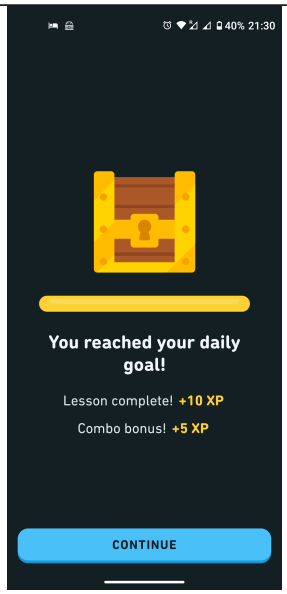
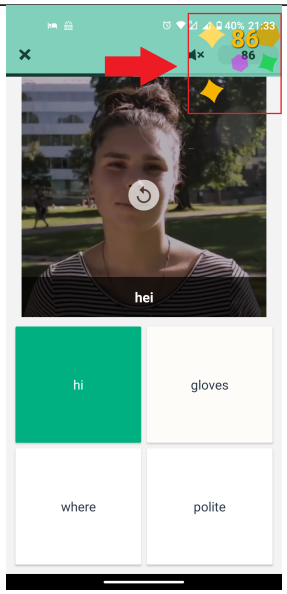
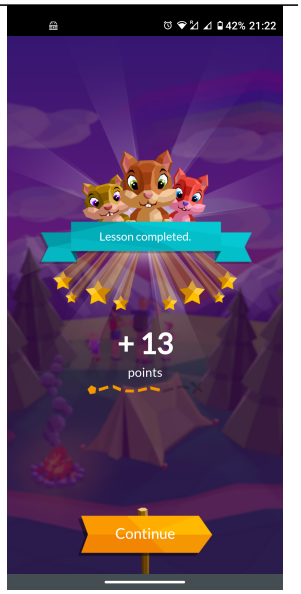
Looking back, "Fill In The World" has become a unique gamified learning application that allows children to learn collaboratively, unlike any of the explored existing applications.

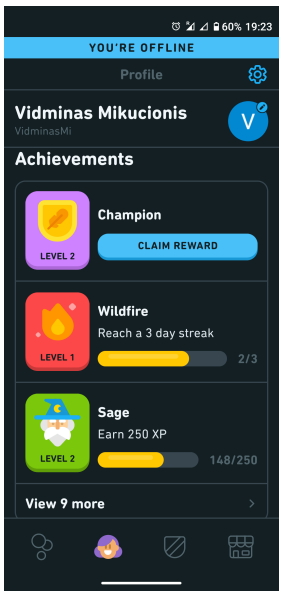
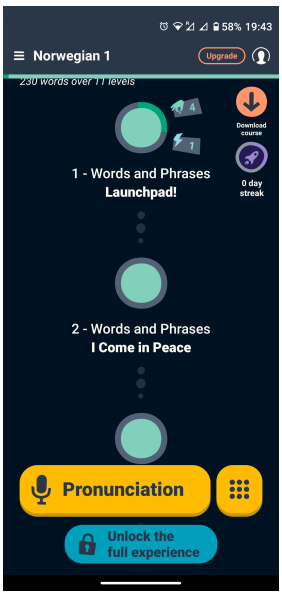
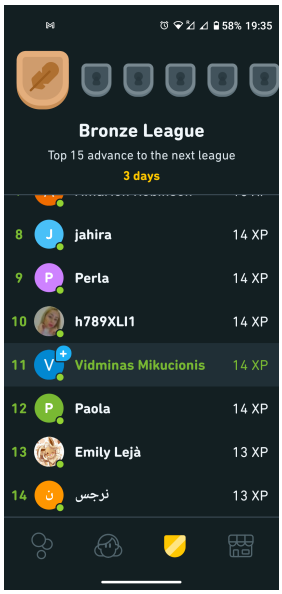
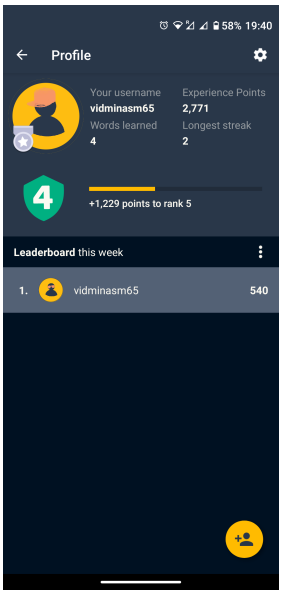
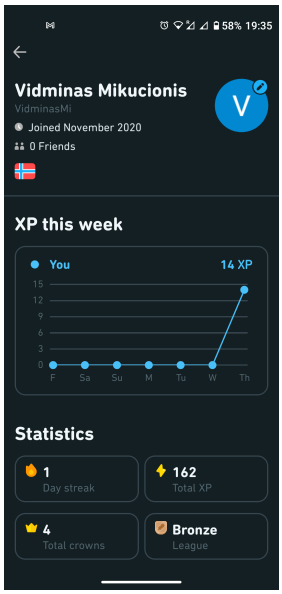
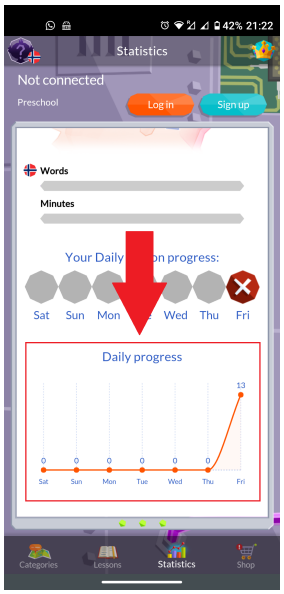
The usability of the game must still be improved and there are multiple useful extensions that ought to be implemented. Once this is done, it could be used in further research about the effectiveness of individual gamification elements, as well as for supporting learning in classrooms.

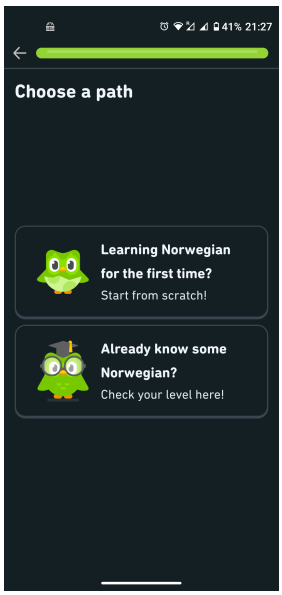
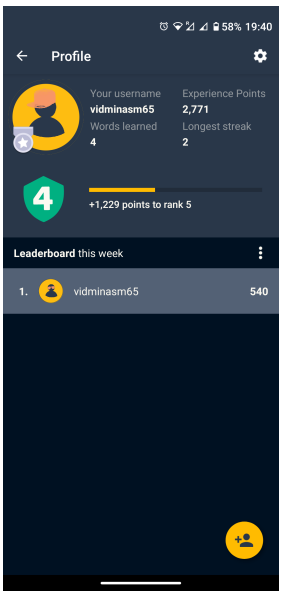
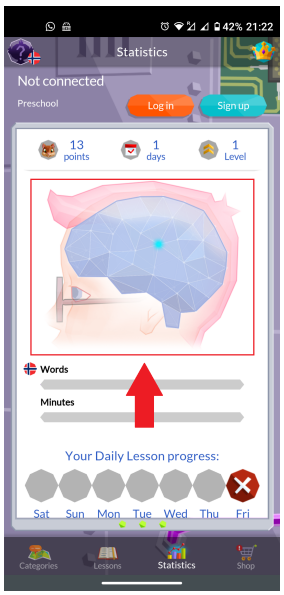
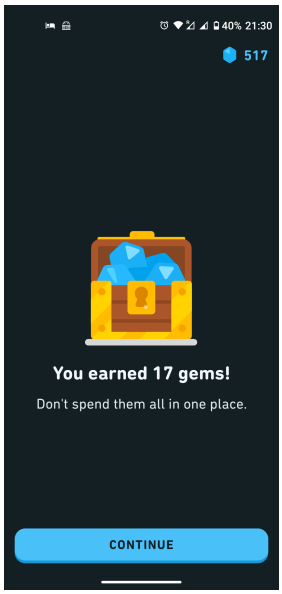
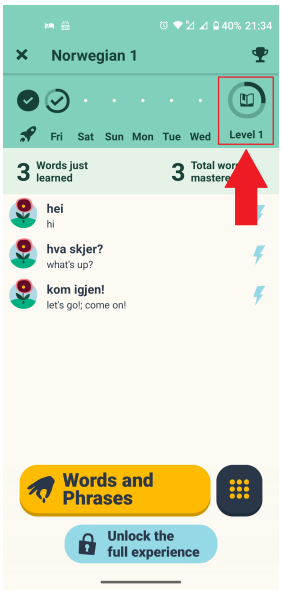
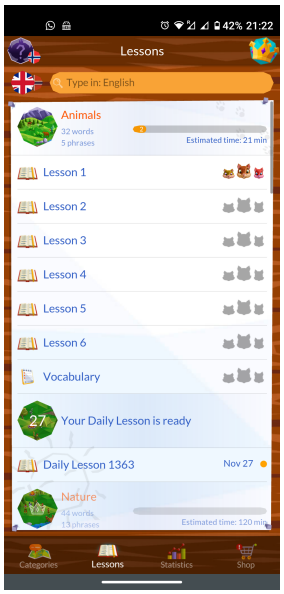
Appendix A

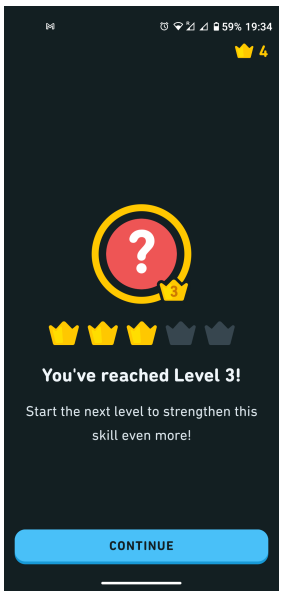
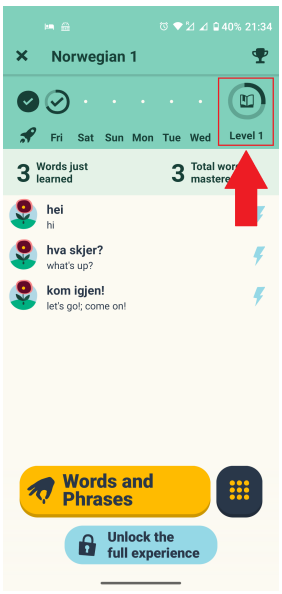
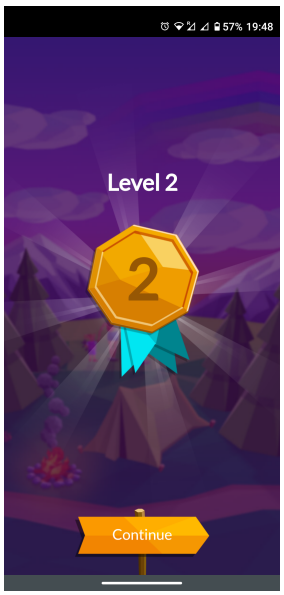
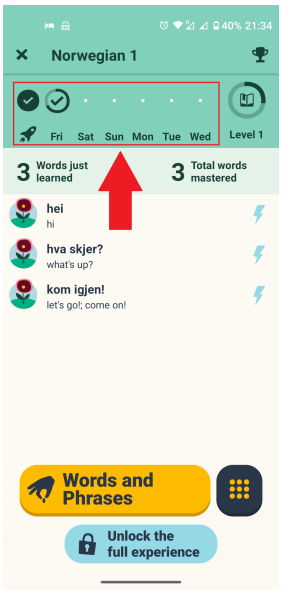
Tables and figures

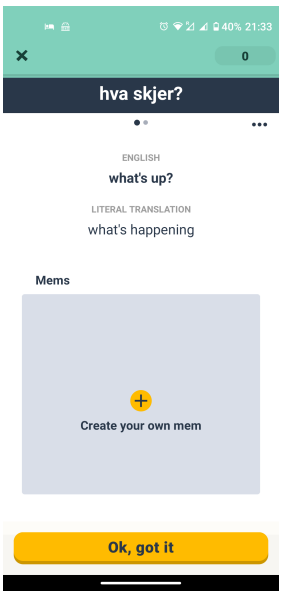
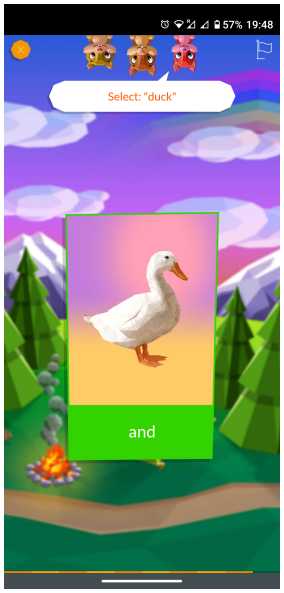
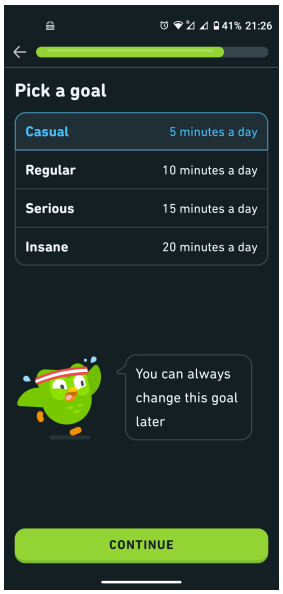
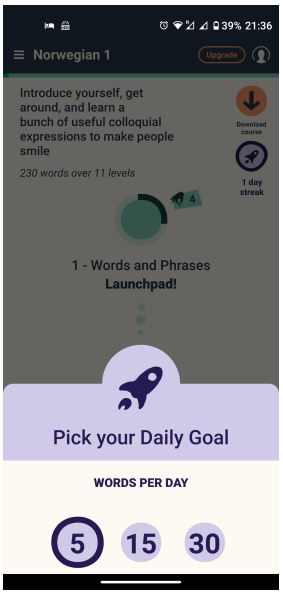
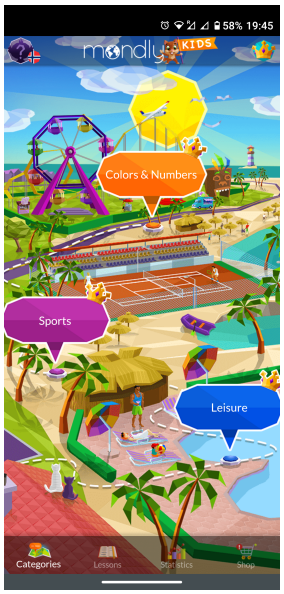
Table A.1: Gamification elements in Duolingo, Memrise, and Mondly for Kids

Gamification element	Duolingo	Memrise	Mondly for Kids
Points			
Side Narratives	N/A	N/A	N/A
Teams	N/A	N/A	N/A

Milestones			N/A
Leaderboards			N/A
Performance Graphs		N/A	

Avatars			
Virtual Currency		N/A	N/A
Progress Bars			

Levels			
Winning Streaks			
Health Points		N/A	N/A

Encouragements		 (The plant in the top right grows from a seed to a full sunflower as you get questions right)	 (There are lots of cheering sound effects when you get questions right)
Personal Goals			 (Not a numeric goal like the others, but you can choose any topic you want to learn)

Disclaimer: this table does not and is not meant to include all the gamification elements in these applications – it just showcases some examples.

Table A.2: Example server logs

[25/03/2021, 16:27:38] admin: connected
[25/03/2021, 16:25:16] mongodb: Failed to initialise database because: connect ECONNREFUSED 127.0.0.1:27017
[25/03/2021, 16:24:46] server: Server started. Listening on port 8081

[25/03/2021, 20:51:13] server: Saved user ”The Developer” to DB
[25/03/2021, 20:51:13] server: Updated world ”A Beautiful World” in DB
[25/03/2021, 20:51:13] PCyAaIUJDoZw3ozXAAAD: disconnected
[25/03/2021, 20:51:12] The Developer: left the world
[25/03/2021, 20:51:12] The Developer: Added world ”A Beautiful World” to The Developer's worlds
[25/03/2021, 20:51:03] The Developer: deleted fitwick pine tree at [3110.1996684669266,472.7622547401054]
[25/03/2021, 20:51:01] The Developer: picked up fitwick pine tree from [3110.1996684669266,472.7622547401054]
[25/03/2021, 20:50:39] The Developer: placed fitwick lake at [2975.1737340249183,747.090161288711]
[25/03/2021, 20:50:37] The Developer: created new fitwick lake at [3284,587.75]
[25/03/2021, 20:50:23] The Developer: placed fitwick pine tree at [3110.1996684669266,472.7622547401054]
[25/03/2021, 20:50:21] The Developer: created new fitwick pine tree at [2964,587.75]
[25/03/2021, 20:50:16] The Developer: placed fitwick house at [3377.958611838939,557.9317226474557]
[25/03/2021, 20:50:14] The Developer: created new fitwick house at [2964,587.5]
[25/03/2021, 20:50:01] The Developer: changed background to backgroundColorFall.png
[25/03/2021, 20:49:51] The Developer: The Developer entered A Beautiful World
[25/03/2021, 20:49:51] server: Created new world ”A Beautiful World” in DB
[25/03/2021, 20:49:50] PCyAaIUJDoZw3ozXAAAD: connected
[25/03/2021, 20:49:50] routes/worlds: GET /?id=6057389fce25b70f4dce5a0c
[25/03/2021, 20:49:23] local user auth: Successfully validated user The Developer
[25/03/2021, 20:49:23] local user auth: Verifying locally cached user with ID 601ad08326976baf00f74e48
[25/03/2021, 20:48:20] mongodb: Successfully initialised MongoDB database
[25/03/2021, 20:48:19] server: Server started. Listening on port 8081

Note: these example logs are from running the server and client on `localhost`. The user and world data mentioned in these logs are not live server data.

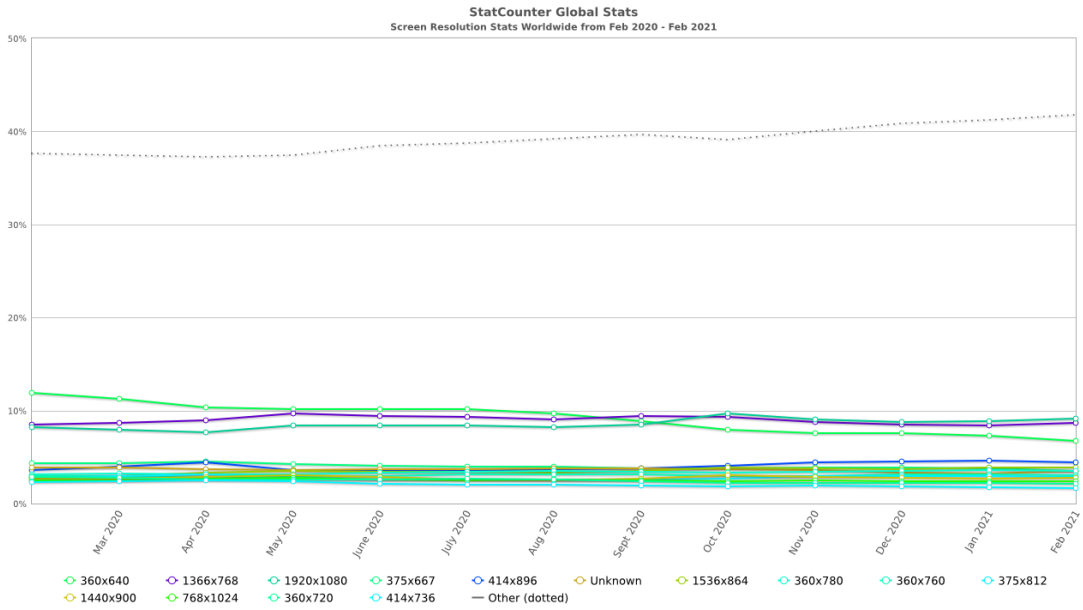


Figure A.1: globalstats StatCounter internet user screen resolution statistics

Appendix B

Usability evaluation results

Pilot study #1 (March 19, 2021), anonymous:

Notes	Codes
https://10minutemail.com or https://emailfake.com are good for privacy, but not reusable after the study and too complicated for non-technical users to setup (because it requires lots of tab switching). Better if either I setup an email address for them in advance, or we use a real one.	Study Protocol
Chrome/Safari on iOS: CSS `backface-visibility` is broken, images show on both sides of pages in the World Book	Graphical Bug
Small objects are difficult for kids to click – if they are struggling, explain how to zoom in/out	Study Protocol
It is not obvious that you must confirm one object placement before you can pick up another, the game should allow swapping.	Interaction
It was way too easy to skip names of items. It might help if the names are spoken out loud when items are picked up.	Interaction Problem
Zooming out to see more of the world would be nice	Interaction
Some backgrounds simply would not load, although they would adjust the game scale correctly; no idea why, maybe I can hook in an error listener to Phaser?	Graphical Bug, Error Handling
The errors that pop up when adding an object with a name typo are useful for parents, but learners cannot read them. Errors should be logged server-side, so I can help debug by seeing what they typed.	Error Handling
Need a close button on the world item list, the modal area is too small on small screens.	**Critical UX Problem**

Pilot study #2 (March 25, 2021), anonymous:

Notes	Codes

The game should ignore if the letters are uppercase or lowercase – "Saw" was not recognised because it had to be "saw".	Gameplay Problem
Why is there no ice cream in the game?	Content
Switching between a phone and a tablet was easy with the same user, because they were already logged into their email on both, so the same login link worked	Access, Device Compatibility
They made 2 worlds with the same name, which got very confusing for me; it's good that worlds can be renamed, and that different backgrounds help to differentiate even if it's the same name	Gameplay
The easiest way to find out names of fitwicks is through the fitwick list. This list is often used and it is an issue that it takes a while to load every time.	Interaction, Performance Problem
It took too long trying to get the toolbox badge: only about 5-7 tool fitwicks were interesting, then we switched to building some more crazy things	Gameplay

Pilot study #3 (March 27, 2021), anonymous:

Notes	**Codes**
I should make the badge toast message last longer, it disappears too quickly to read for non-native speakers	UX Problem
Add "loading" text to the game loading bar, otherwise with just the $0-100\%$ it's not clear what is happening	UX Problem
Instead of "time now" show a clock icon in the top toolbar, otherwise it looks like very urgent, like a countdown	UX Problem
The pine tree fitwick is actually half fir, half birch??	Content
The game needs cars and princesses	Content
Long-press delay is too long on touch devices	UX Problem

Official study #1 (March 31, 2021) with participant "žalias zebras" (age 9):

Notes	**Codes**
`/game` page using Firefox on Windows did not show loading progress, might be related to slow internet?	Performance Problem
It did not load even after 5 minutes, so we switched to Edge. It still did not load the game. The login page took considerably longer than on any machines I had tested on. The game loading time could be improved by lazy loading assets.	**Critical Performance Problem**
We agreed to leave it loading and return in 30 minutes. The game did load after 10 minutes (as seen from server logs), but game textures were missing until the page was reloaded.	**Critical Graphical Bug**

The participant and their dad figured out all the controls of the game and even got the tree badge before we met 30 minutes later. We then focused on getting the pyramid badge as well.	Interaction, Gameplay
They tried to add "sand" for the pyramid badge. This is appropriately desert themed, but there's no sand object in the game.	Gameplay, Content
Q & A	
1. Can you tell me something that you liked in Fill in the World? Writing English words *2. Can you tell me something that you disliked in Fill in the World?* I don't know *3. Have you played any other language learning games?* I played a similar learning game in English class, but I needed to write words there. I don't know what I liked or disliked. *4. Have you played any games like Fill in the World?* Not language learning, but I played Roblox a lot. *5. Can you tell me any words that you learned by playing today?* Tree, palm tree, cactus *6. Was the amount of work you had to do to get the badge too little, too much, or just right?* We got both the tree and the pyramid badge. The effort was just right. *7. What would be reasonable to ask for the next badge?* I don't know. *8. Is there anything you would like to add or ask about?* Maybe the game could have a spade?	

Official study #2 (March 31, 2021) with 2 participants as "Au Au" (ages 8 and 11):

Notes	Codes
On Galaxy Tab S6 Lite using Samsung Internet and Chrome browsers, the game was only using half of the screen height, but full width. Adjusting the Android display ¿ screen zoom setting to zoom in more seemed to help make it full screen.	Graphical Bug
None of the buttons worked with Samsung Internet (they turned green, but no dialog opened), switching to Chrome helped.	Device Compatibility Problem
Opening the world item list would cause the entire game to go black and freeze (including the timer), most likely the CPU was completely hogged by loading items.	**Critical Performance Problem**
Every time they turned the tablet to a different orientation, it would lock the tablet, which caused interruptions.	Other

Samsung Tab A, their other tablet, also did not work. When the `/game` page was opened, it would just stay black (except for the clock at the top). After multiple reloads, it did eventually load (probably just the loading screen did not show up and it took a while), but after loading the buttons were not responsive at all. The parent who helped was very patient, but the children were getting frustrated by now. We decided to try their desktop computer as the last effort. It worked straight away from the first time. Deleting items with a small button using a mouse was exceedingly difficult. This works on touch interfaces, but for mouse. Maybe the button could appear next to the item, or double click could remove it. Something that doesn't require dragging a long distance many times. The server logs show that they joined the game in the next 2 days multiple times	**Critical Device Compatibility Problem** Device Compatibility UX Problem
Q & A	
1. Can you tell me something that you liked in Fill in the World? Setting new world background, changing music, I would like to have more music tracks *2. Can you tell me something that you disliked in Fill in the World?* Nothing *3. Have you played any other language learning games?* Both had played educational games in school before using www.oli.lu. One of them enjoyed games that were easy. *4. Have you played any games like Fill in the World?* Maybe MineCraft? *5. Can you tell me any words that you learned by playing today?* Snowy tree, pine tree, monkey wrench *6. Was the amount of work you had to do to get the badge too little, too much, or just right?* It was just right. *7. What would be reasonable to ask for the next badge?* Add 100 objects to the game for the Infinity Badge is too much, 15 would be better. There could be a badge for adding 15 objects and the another one for adding 20. *8. Is there anything you would like to add or ask about?* –	

Official study #3 (April 02, 2021) with participants "misteriukas" (age 13) and "Ice Gamer" (age 11):

Notes	Codes
Registering two accounts and sending two login emails in a row makes the first one not work! That is, only one login link can be valid at a time.	Access Problem

Once logged in, the game loaded for both of them very quickly without any trouble (using a Windows desktop and MacBook laptop)	Performance
On a MacBook, scrolling the mouse to the left at a world's edge makes the browser navigate back to the World Book, which is very disruptive.	Interaction Problem
"misteriukas" completed the Tree Badge extremely quickly (it only took a minute) without any help, and started trying to get the electronics badge without even being told to do so.	Gameplay
"misteriukas" tried adding the RAM fitwick, but it didn't work. In the server logs, I could see "misteriukas: warning: Unknown object "RAM". Did you mean "RAM"?" this must be because I lowercase all input, without lowercasing the fitwick name (assumed they were all lowercase already)	**Critical Interaction Problem**
"Ice Gamer" tried adding an "oak" to the game when getting the Tree Badge, but it didn't exist	Gameplay, Content

Q & A

1. Can you tell me something that you liked in Fill in the World?
misteriukas: Very easy to create worlds, very easy to navigate and see objects the world
Ice Gamer: I liked that items are easy to find from the item list
2. Can you tell me something that you disliked in Fill in the World?
Ice Gamer: I did not like that when I create a new world, I try to edit the world name, but clicking on the world name makes the modal disappear
3. Have you played any other language learning games?
misteriukas: not really
Ice Gamer: once, but not sure what it was called, and I don't remember much about it
4. Have you played any games like Fill in the World?
misteriukas: not really
Ice Gamer: no
5. Can you tell me any words that you learned by playing today?
Ice Gamer: skull
misteriukas: I already knew all the words
6. Was the amount of work you had to do to get the badge too little, too much, or just right?
Ice Gamer: it was just right
misteriukas: it was just right or maybe a little too easy
7. If you designed a badge yourself, what would it be?
misteriukas: there could be a badge "building a PC", which requires adding all the parts that would be needed to build a real computer
Ice Gamer: have a badge for construction items, maybe building 10 would be good
8. Is there anything you would like to add or ask about?
Ice Gamer: if you want to change a letter in a word when adding a fitwick, you have to delete the whole word and rewrite it, you can't select in the middle of the text
misteriukas: it would be cool if the view was 3D or at least isometric, so you could see objects from different angles

both: it would be nice to be able to share worlds and build them together without having to ask the developer to manually share them

Official study #4 (April 05, 2021) with 2 participants as "Labas" (ages 6 and 9):

Notes	Codes
Both participants logged in successfully with the same user, but after refreshing the page, one of them (using a tablet) got logged out and needed to use the email link to open the game again. This worked okay for the one using the desktop.	Access
For one of them (using the desktop), all the existing worlds were displayed, while the other one (using the tablet) could only see the workshop.	Gameplay Problem
Especially with small items, it was not obvious when an item was picked up (when it turns green), and thus clicking on other game objects did not show their name.	Interaction Problem
They managed to navigate the game without explanation otherwise	Interaction
To delete items, they tried dragging them to the bin button instead of pressing on the bin (which also works, but is unnecessarily difficult)	Interaction Problem
They loved changing game backgrounds	Engaged
At first, the backgrounds changed for both simultaneously just fine, but after a minute, the scifi planets background did not work on the tablet anymore (it would set to the current background but with the wrong dimensions) while it still worked fine on the computer. It was just this background, the others still worked.	Device Compatibility Problem
Soon enough, they started explaining to each other how to play, I did not even need to do anything	Collaborative Gameplay
They came up with a game of their own, chasing each other with items in the same world	Collaborative Gameplay, Engaged
Having found everything they could do, they got bored after about 5 minutes and started asking if there was another game we could play. This changed after finding badges.	Bored, Gamification
Despite being 6, the smaller one already could write words (with some help for spelling). She is quite advanced for her age, her mum says. It was difficult for her to get the tree badge herself, but she watched her older sister get it and placed some trees herself.	Age-related
The older one instantly started trying to get the planet badge after the tree one without any instruction.	Engaged
The younger one started copying her older sister and began creating new worlds to get the Planet Badge.	Engaged
The older one was surprised, why didn't she get any points for creating new worlds and getting the planet badge?	Gamification Problem

The game was not full screen on the tablet, but it was on the desktop.	Device Compatibility Problem
The fitwick item list font size was a bit too small on the tablet. The little one tried writing "crown 1" instead of "crown", because she could not read it very well.	Device Compatibility Problem, Age-related
The older one asked me to add planet fitwicks into the game.	Content
The older one enjoyed that the point chart always only went as high as she had points, which meant her highscore always showed at the top.	Gamification
The message that someone came into the world or left disappears too quickly, no one managed to read it.	UX Problem
The older one asked "is it a good thing to have badges?". She was excited to hear that it is, and that she can try to earn the other badges later if she wants.	Gamification, Engaged
After hearing that the infinity badge needs 100 created objects, the older one tried to make loads of bubbles and crowns right away.	Gamification, Engaged
The girls managed to ignore the word pronunciations while playing, because they were mostly just adding new items and the music was drowning out the voice audio when each item was created.	Gameplay Problem
Q & A	
1. Can you tell me something that you liked in Fill in the World? "Creating houses, creating objects". "Choosing drawings". *2. Can you tell me something that you disliked in Fill in the World?* "I didn't like when my sister changed the background and it also changed for me in the same world". "Nothing" [but I noticed that she did get upset when her sister came into a new world she made and deleted some objects there]. *3. Have you played any other language learning games?* "Antolin" – you have to read a book, and then do a reading comprehension test about the book, it's just gathering points by answering questions. *4. Have you played any games like Fill in the World?* "Not really, they play lots of different educational games at school, but none of them allow so much creativity." Maybe "Scrabble Junior" (the board game) because it also requires creating words. "I like making the words 'dress', 'cloud', 'bag' on the board". "I do not like that I have to look up words in a dictionary to play". *5. Can you tell me any words that you learned by playing today?* "bubble, tree" "crown, bubble" [I noticed that they mispronounced 'bubble' and 'crown', but they got 'tree' right – the only word of these 3 that had a voice recording in the game] *6. Was the amount of work you had to do to get the badge too little, too much, or just right?*	

"It was difficult to get 5 different trees".
7. If you designed a badge yourself, what would it be?
"a badge for creating 20 crowns".
"a badge for creating 10 bubbles".
8. Is there anything you would like to add or ask about?
–

Official study #5 (April 06, 2021) with participants "KOKO" (age 6) and "KIKI" (age 10):

Notes	Codes
Using a tablet (Samsung Galaxy Tab 2), the loading progress bar does not show when entering a world for the first time. Not sure why...	**Critical Graphical Bug**
Why aren't the confirm/delete buttons next to items when you pick one up?	UX Problem
There could be a toolbox on the ground where they could place items instead of deleting them.	Content
They accidentally refreshed the game page while in the workshop. Then the world book got frozen on the world dialog, and they could not enter the workshop again, even after refreshing. We switched to an iPhone instead.	**Critical Device Compatibility Problem**
I realised why some users see all worlds – when their worlds array is empty, it does a `GET /` request which returns all existing worlds.	UX
The UI loaded properly on the smartphone; it was broken on the tablet for some reason.	Graphical Bug
After exiting the workshop world on the smartphone, they had to log in again, for some reason the user was not saved. But the same login email link works.	Access Problem
The tablet started working after multiple tries, but the world loading progress was still not displayed.	Graphical Bug
On iPhone 8, the fitwick name input box does not show entered text until the keyboard is closed.	Graphical Bug
When at the left edge of the world on the iPhone 8, dragging to the left went back a page which kicked them out of the world.	Interaction Problem
Why is there no indication when you receive a badge? It was not obvious it was now obtained in the book.	UX Problem
There is a long delay when opening the fitwick list on the tablet, while it works quickly on the smartphone.	Performance Problem

I couldn't download the server logs because the server and client apps stopped after our study – apparently the service plan Data Out quota (of 666.8MB / 24h) was exceeded. The same quota is set for both client and server from a shared batch, but only the client needs that much. Not sure if I can share the quotas between them. For any larger scale trials, I will have to upgrade to paid hosting.	
Q & A	
1. Can you tell me something that you liked in Fill in the World? KIKI: "I liked that I could create anything I wanted in the world". *2. Can you tell me something that you disliked in Fill in the World?* KIKI: "I wanted the game to have a burning tree". *3. Have you played any other language learning games?* Their parents: "Yes – English learning games for kids. They not like some that were too easy (there were too many encouragements like "Good job" every 1-2 answers, which was annoying)" Their parents: They liked 'Lingo Kids' which has lots of minigames, although it might have messed up the balance between game and learning elements (too much game, too little learning). A more important problem with 'Lingo Kids' is that it is very expensive – 15 euros per month. *4. Have you played any games like Fill in the World?* KIKI: "MineCraft! I like that I can do whatever I want, there is no end in the game. There are many kinds of blocks I can use to build. There are also different kinds of mobs. I can be as creative as I want without many limitations. I don't like that all mods are paid. I don't like that there is a game world height limit." *5. Can you tell me any words that you learned by playing today?* KIKI: "tree, dead tree" *6. Was the amount of work you had to do to get the badge too little, too much, or just right?* KIKI: "It was too easy. I only had to write words. I made mistakes twice, it helped that there was a message." *7. If you designed a badge yourself, what would it be?* KIKI: "For creating the biggest and coolest city, with skyscrapers or a pyramid or a park, or a space base". *8. Is there anything you would like to add or ask about?* –	

Collected server logs in JSON format can be found in the project materials archive.

Appendix C

Interview evaluation study documents

These documents only include the English versions of the information sheet, data management plan, and study plan. You can also find the rest of the documents (consent forms and all translated Lithuanian versions) in the project materials archive.

Participant Information Sheet

Project title:	Implementing gamification elements in children's online language learning
Principal investigator (PI):	Judy Robertson
Researcher collecting data:	Vidminas Mikucionis

This study was certified according to the Informatics Research Ethics Process, RT number 81164. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

Professor Judy Robertson is Chair in Digital Learning at the University of Edinburgh. She is a researcher, learning technologist, and computer scientist at the School of Informatics and Moray House School of Education and Sport.

Vidminas Mikucionis is a 4th year undergraduate student in Computer Science and Management Science at the University of Edinburgh, working on this final year project under the supervision of Professor Robertson.

What is the purpose of the study?

This research project is about developing a language learning game for primary school children to explore different gamification elements that can be implemented and their effectiveness.

Why have I been asked to take part?

The target research groups in developing the game prototype are educators, who work with primary and secondary school children, and parents. Your involvement will help to improve the project with participatory design.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, up until 22 March 2020 without giving a reason. After this point, personal data will be deleted, and anonymised data will be combined such that it is impossible to remove individual information from the analysis. Your rights will not be affected. If

you wish to withdraw, contact the PI. We will keep copies of your original consent, and of your withdrawal request.

What will happen if I decide to take part?

You will take part in a semi-structured interview about teaching languages to primary school children, and try out a design or prototype of the game, over an online call on Microsoft Teams. The session should last about 45 minutes. The researcher will take notes about your thoughts and observations.

During the interaction with the design or prototype app, you will be asked to share your screen and think aloud to help see what works well and what does not.

With your permission, the interview may be audio recorded and the prototype interaction may be audio+video recorded, to allow reviewing it in more detail after the session.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no immediate benefits from taking part in this study, although your feedback will be considered in the development of the language learning game, and you will be able to download it for your own use once the project is complete.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports, and presentations. Quotes or key findings will be anonymized: we will remove any information that could, in our assessment, allow anyone to identify you. With your consent, information will be publicly archived after 22 March 2020, so it can be used for future research. All potentially identifiable data will be deleted before archiving if it has not already been deleted as part of anonymization.

Data protection and confidentiality.

Your data will be processed in accordance with Data Protection Law. All information collected about you will be kept strictly confidential. Your data will be referred to by a

unique participant number rather than by name. During the project, your data will only be viewed by the researchers Judy Robertson and Vidminas Mikucionis.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (SharePoint, OneDrive For Business, DataStore, or DataShare). Your consent information will be kept separately from your responses in order to minimise risk.

What are my data protection rights?

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments, and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Vidminas Mikucionis, at s1750767@ed.ac.uk.

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Vidminas Mikucionis, at s1750767@ed.ac.uk.

General information.

For general information about how we use your data, go to: edin.ac/privacy-research

IMPLEMENTING GAMIFICATION ELEMENTS IN CHILDREN'S ONLINE LANGUAGE LEARNING DATA MANAGEMENT PLAN

Creator: Vidminas Mikucionis

Affiliation: University of Edinburgh

Project abstract:
This research project is about developing a language learning game for primary school children to explore different gamification elements that can be implemented and their effectiveness.

Last modified: 21-11-2020

ADMINISTRATIVE INFORMATION

School or Institute

- CSE - School of Informatics

Name and Contact details of supervisor(s)

Professor Judy Robertson, Judy.Robertson@ed.ac.uk

Project start date

2020-09-21

Project end date

2021-04-01

DATA COLLECTION

Data Capture

Qualitative data from interviews: notes, audio, and video recordings, will be collected through individual calls with educators and parents when testing the project design or prototype.
Recordings will be stored in MP4 file format and notes will be saved in plaintext or markdown files.

Amount of Captured Data

Between 0-50GB of data will be collected in total.

DOCUMENTATION & METADATA

Study Metadata

To help make the study reproducible, the study plan (including study design and sampling methodology), and any materials shared with the participants (including tested versions of designs and prototype implementations) will be stored as project metadata.

ETHICS & LEGAL COMPLIANCE

Ethics & Legal Compliance

For interviews, all collected interview notes will be anonymised before being stored.
Video and audio will only be recorded with opt-in signed participant's consent. Since the recordings will inevitably contain personal data, each participant will be given a unique identifier, and their data will be stored with the identifiers instead of names up until 22 March 2020.
Consent information will be stored separately from responses to minimise risk.
Participants will be able to see their recordings and notes during and after their interviews, which will become no longer possible after anonymization. On 22 March 2020, the recordings and any data from individuals who do not consent to archiving will be deleted, so that only anonymous data from consenting individuals is left. After this date, the anonymous notes will be archived together with the research findings on Edinburgh DataShare or alternative secure public repository.

STORAGE AND BACK-UP

Where will your data be stored and backed-up during the project?

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, or on the University's secure encrypted cloud storage services (SharePoint, OneDrive For Business, DataStore, or DataShare).

SELECTION AND PRESERVATION

Where will the data be stored long-term?

After 22 March 2020, research data will be published to DataShare or alternative secure public repository, to make it publicly available together with the research findings.

Which data will be retained long-term?

Anonymous notes about observations and conclusions from the interviews, collected from consenting individuals, will be archived perpetually.

DATA SHARING

Will the data produced from your project be made open?

Yes

How will you maximize data discoverability & access?

There are no restrictions on sharing collected anonymous notes, provided that all participants have signed consent forms. These will be published on the Edinburgh DataShare or alternative secure public data repository upon project completion.

RESPONSIBILITIES & RESOURCES

Who will be responsible for the research data management of this project?

Vidminas Mikucionis, s1750767@ed.ac.uk

Will you require any training or resources to properly manage your research data throughout this project?

Yes - I have already completed the Data Protection and Data Protection in Research training but will ask my supervisor for support with managing research data appropriately.

Educators & Parents interview study

Goal: involve key stakeholders in the design and development of the application.
Collected data: qualitative data - interview answers and observed interactions with designs/prototypes.

[Before calling, send PIS - ask participants to read it, and send consent form – ask them to sign it]

[Call]:

[If obtained consent, inform them about recording, let them know they can turn off their camera if they want to, and start recording]

Hello [participant], my name is Vidminas. Thank you for participating in my study. We will be chatting about how children learn languages and then try a language learning game [design/prototype].

[Pre-test semi-structured interview, about 10 minutes]:
First, I would like to ask you some questions. During our conversation I will be taking notes. This is not a test – I am only taking notes to help remember any points you raise for this research project, and all your feedback is valuable.

[For educators]:

- What subject(s) and year(s) do you teach?
- ~~*How has Covid19 impacted your classes?*~~
- What differences are there between when you teach online vs face-to-face classes?
- How do you rate your computer skills (beginner, intermediate, advanced)?
- Do you use or have you used any game-based learning applications for teaching languages?
    - [If so]: what do you use? what went well, what didn't?
    - [If not]: what do you think about such applications?
- Would you use a game in your online or face-to-face classes now?
- Would you use a game in your online or face-to-face classes after Covid19 is over?

[For parents]:

- How old are your children?
- *How has Covid19 impacted their classes, and subsequently, learning at home?*
- How do you rate your computer skills (beginner, intermediate, advanced)?
- Do your children use or have your children used any game-based learning applications for languages?
    - [If so]: what do you use? what went well, what didn't?
    - [If not]: what do you think about such applications?
- Would you encourage your children to use learning games in classes now?
- Would you encourage your children to use learning games in classes after Covid19 is over?

Thank you very much for your answers.

[Design review preparation, 5-10 minutes]:

Let us try the experiment. The purpose of this exercise is to identify issues with the [design/prototype]. Please remember we are testing the app, not you, so there are no wrong answers.

Please start by sharing your screen with me and opening the link I will send in the chat.

[Design: https://www.figma.com/file/ICKHXQupyukvEkzhMuRn8P/App-Prototype?node-id=12%3A3
Help them open the Figma mock-up in Presentation mode. Show them how to get back to the Main Page by R at any time.]
[Prototype: to be added when complete]

To better understand how you interact with the [design/prototype], I would like to ask you to please speak your thoughts out loud. I want you to tell me everything you are thinking from the first time you see the statement of the task till you finish the task. Please don't plan out what you will say or try to explain yourself to me, just act as if you were alone, speaking to yourself.

As you are using the [design/prototype], please speak aloud any questions you may have. I will take notes and get back to them at the end of the session.

Do you have any questions about the Think Aloud?

Let us begin with a warm-up exercise first. I will show an example by counting how many windows there are in my family home.

[Do think-aloud warm-up exercise]

Now I would like you to please share your thoughts aloud as you count how many countries you have visited in your life.

[Let participant do think-aloud warm-up exercise]

Thank you, you did really well. Keep it up!

[Design review, 10-15 minutes]:
Now let's begin with the [design/prototype].
[Design: Please start by reading aloud the text you see on the pink post-it note, and then press on the phone screen to proceed.]
[Prototype: starting instructions To Be Confirmed]

I will mute myself for now and let you explore the [design/prototype].

[Explore whole design/prototype. Prompt the participant where to go next if they get stuck or think they have finished everything, but haven't seen all the modes yet]

[Post-test semi-structured interview, about 10 minutes]:
That is all for the [design/prototype] exploration.

- Having tried the design,
    - [If language teacher]: would you use this application in your classes to support language learning?
    - [otherwise]: do you think this application would be useful for supporting language learning in classes?

    - Do you think it would take more, less, or the same amount of time from teachers to implement lessons using this application as without?
- What age ranges do you think would be this would be the most suitable for?
- Is there anything you would change, remove, or add in this design?

Thank you for your help today. Talking with you and watching you use the [design/prototype] has helped me better understand how the design is and is not supporting children, educators, and parents.

[Done]

Appendix D

Usability evaluation study documents

These documents only include the English versions of the information sheets for parents and children, data management plan, and study plan. You can also find the rest of the documents (consent forms and all translated Lithuanian versions) in the project materials archive.

Participant Information Sheet

Project title:	Implementing gamification elements in children's online language learning
Principal investigator (PI):	Judy Robertson
Researcher:	Vidminas Mikucionis
PI contact details:	Judy.Robertson@ed.ac.uk
RT number:	RT #5624

Implementing gamification elements in children's online language learning

(may be read aloud to the child)

This page is for children. Some researchers are organising a study **at the University of Edinburgh**. It says who they are, and what they will do **during the study.**
They will ask you to help with testing a language learning game. You can decide if you want to say "yes" or "no" to helping and can **change your mind at any time**.

Who is organising the study?

This is Vidminas and Judy. Their job is to find out what a good language learning game for children should be like.

	
Vidminas	Judy

How can I help?

Vidminas and Judy need children and parents to try the game they have made, called “Fill in the World”. This will help to see how well different parts of the game work for children and to make a better game in the future.

What will happen if I help?

You will need a smartphone, tablet, or laptop. Vidminas will first show how to open “Fill in the World” and give a few tasks to try in the game. Some information about how children use the game will be automatically collected.

Afterwards, Vidminas will ask the children some questions about how they found the game. Overall, this should take about 30 minutes.

You can tell us if you want to stop doing any of the activities. You do not have to tell us why. Please tell us if you need the toilet, or if you want to take a break. You can also say you do not want to help any more, and that is OK. We will always listen to you.

What will happen after I have finished helping?

The researchers will learn a lot about children and learning with games from the things that you do and say when you take part in the study. They will write about what they have learned and use it to make a better game.

Do you want to ask a question?

It is OK to have more questions. You can ask the researchers as many questions as you want about the experiment. Ask your mum or dad to help you call them on the phone or write an email with your question.

Participant Information Sheet – for parents and guardians

Project title:	Implementing gamification elements in children's online language learning
Principal investigator (PI):	Judy Robertson
Researcher:	Vidminas Mikucionis
PI contact details:	Judy.Robertson@ed.ac.uk

This information sheet is for parents and guardians. It explains the research project at the University of Edinburgh, in which we would like you and your child to participate. It gives information about the project in the form of questions you might have and their answers. If you have further questions, we are happy to discuss them and give you more information.

This study was certified according to the Informatics Research Ethics Process, RT number 5624. Please take time to read the following information carefully. A shortened version of this information will be provided and read aloud to your child should you agree to their participating in the project. You should keep this page for your records.

Who are the researchers?

Professor Judy Robertson is Chair in Digital Learning at the University of Edinburgh. She is a researcher, learning technologist, and computer scientist at the School of Informatics and Moray House School of Education and Sport.

Vidminas Mikucionis is a 4th year undergraduate student in Computer Science and Management Science at the University of Edinburgh, working on this final year project under the supervision of Professor Robertson.

What is the purpose of the study?

This research project is about developing a language learning game for primary school children to explore different gamification elements that can be implemented and their effectiveness.

How can I and my child help?

This research project is a pilot study about the effectiveness of gamification in applications used for language learning. Feedback from you and your child, and usage data from your child playing the game will help to evaluate the usability of the developed application and its suitability for conducting further research about language learning.

Do I or my child have to take part?

No – participation in this study is entirely up to you and your child. You can withdraw yourself or your child from the study at any time, without giving a reason. Your child may also withdraw at any time by saying that s/he does not want to take part anymore. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your or your child's data (as applicable) in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your and your child's original consent, and of your withdrawal request.

What will happen if I and my child take part?

You and your child will be invited to meet a researcher and test the game prototype. If meeting in person is not possible, the meeting can also take place online, using Microsoft Teams (or similar application). You will need a smartphone, tablet, or laptop during the meeting. The session should last about 30 minutes.

In the meeting, your child will get a few tasks to complete while playing the game. Data about your child's interactions with the game will be collected (for example, where clicks or swipes occurred on the screen), which will help to analyse the game after the meeting (for example, which buttons were used most, and which tasks took longer than others).

After completing all the tasks, the researcher will ask you and your child for your opinion on a few questions about how you found the game as a tool for children to learn languages.

Are there any risks associated with taking part?

There are no significant risks associated with participation.

Are there any benefits associated with taking part?

There are no immediate benefits from taking part in this study, although your feedback will be considered in the development of the language learning game, and you will be able to download it for your own use once the project is complete.

What will happen to the results of this study?

The results of this study may be summarised in published articles, reports, and presentations. Quotes or key findings will be anonymized: We will remove any information that could, in our assessment, allow anyone to identify you or your child. With your consent, information can also be used for future research. Your and your child's data may be archived for a minimum of 4 years.

With your consent, collected data will be stored on a public data archive after 01 June 2021, so it can be used for future research. You may change your mind and opt-out or opt-in any time before 01 June 2021. All potentially identifiable data will be deleted before archiving if it has not already been deleted as part of anonymization.

How will personal information be protected?

Your and your child's data will be processed in accordance with Data Protection Law. All information collected about you and your child will be kept strictly confidential. Your child's data will be referred to by a unique participant username (such as "Green Lion") and your data will be referred to by a unique participant number rather than by name. During the project, your and your child's data will only be viewed by the researchers Judy Robertson and Vidminas Mikucionis.

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, on the University's secure encrypted cloud storage services (SharePoint, OneDrive For Business, DataStore, or DataShare) or on secure GDPR-compliant Microsoft Azure cloud services (restricted to UK-based data centres only), and all paper records will be stored in a locked filing cabinet in the PI's office. Your and your child's consent information will be kept separately from your / your child's data in order to minimise risk.

What are my and my child's data protection rights?

The University of Edinburgh is a Data Controller for the information you and your child provide. You have the right to access information held about you and your child. Your right of access can be exercised in accordance Data Protection Law. You

also have other rights including rights of correction, erasure, and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments, and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Vidminas Mikucionis, at s1750767@ed.ac.uk.

If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title, and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Alternative formats.

To request this document in an alternative format, such as large print or on coloured paper, please contact Vidminas Mikucionis, at s1750767@ed.ac.uk.

General information.

Once again, **this study is completely voluntary, and you and your child are under no obligation to take part.** Even if you say yes now, you may withdraw yourself or your child from the study at any time and for any reason by contacting us. Your child may also withdraw at any time by say that s/he does not want to take part anymore.

For general information about how we use your and your child's data, go to: edin.ac/privacy-research

Thank you for taking the time to read this.

IMPLEMENTING GAMIFICATION ELEMENTS IN CHILDREN'S ONLINE LANGUAGE LEARNING DATA MANAGEMENT PLAN

Creator: Vidminas Mikucionis

Affiliation: University of Edinburgh

Project abstract:
This research project is about developing a language learning game for primary school children to explore different gamification elements that can be implemented and their effectiveness.

Last modified: 27-02-2021

ADMINISTRATIVE INFORMATION

School or Institute

- CSE - School of Informatics

Name and Contact details of supervisor(s)

Professor Judy Robertson, Judy.Robertson@ed.ac.uk

Project start date

2020-09-21

Project end date

2021-04-12

DATA COLLECTION

Data Capture

- quantitative data – usage data (clickstream with timestamps, gestures, time spent on each screen) in JSON format, rating on a smiley-o-meter, application error logs.
- qualitative data – feedback about what children and parents thought about the app's suitability for children, what liked, disliked, and what could be added, changed, or removed. Also, any application error logs. Notes will be saved in plaintext or markdown files.

Amount of Captured Data

Between 0-50GB of data will be collected in total.

DOCUMENTATION & METADATA

Study Metadata

To help make the study reproducible, the study plan (including study design and sampling methodology), and any materials shared with the participants (including tested versions of designs and prototype implementations) will be stored as project metadata.

ETHICS & LEGAL COMPLIANCE

Ethics & Legal Compliance

Children's usage data will be collected under randomly assigned unique pseudonyms (such as "Green Lion") without any personal information.
For verbal feedback, all collected notes will be anonymised before being stored.
Consent information will be stored separately from responses to minimise risk.
Participants will be able to see researchers' notes during and after the study, which will become no longer possible after anonymisation. On 01 June 2021, any data from individuals who do not consent to archiving will be deleted, so that only anonymous data from consenting individuals is left. After this date, the anonymous notes will be archived together with the research findings on Edinburgh DataShare or alternative secure public repository.

STORAGE AND BACK-UP

Where will your data be stored and backed-up during the project?

All electronic data will be stored on a password-protected encrypted computer, on the School of Informatics' secure file servers, on the University's secure encrypted cloud storage services (SharePoint, OneDrive For Business, DataStore, or DataShare) or on secure GDPR-compliant Microsoft Azure cloud services (restricted to UK-based data centres only), and all paper records will be stored in a locked filing cabinet in the PI's office.
Consent forms will be stored separately from collected usage data and feedback.

SELECTION AND PRESERVATION

Where will the data be stored long-term?

After 01 June 2021, research data from consenting participants will be published to DataShare or alternative secure public repository, to make it publicly available together with the research findings.

Which data will be retained long-term?

- Anonymous notes about observations, and conclusions from consenting children and parents
- Anonymised feedback quotes and ratings
- Pseudonymised collected usage data and error logs without linking identifiers (therefore anonymous data)

DATA SHARING

Will the data produced from your project be made open?

Yes

How will you maximize data discoverability & access?

There are no restrictions on sharing collected anonymous notes, provided that all participants have signed consent forms. Other collected data will be added only with opt-in consent. The research data will be published on the Edinburgh DataShare or alternative secure public data repository upon project completion.

RESPONSIBILITIES & RESOURCES

Who will be responsible for the research data management of this project?

Vidminas Mikucionis, s1750767@ed.ac.uk

Will you require any training or resources to properly manage your research data throughout this project?

Yes - I have already completed the Data Protection and Data Protection in Research training but will ask my supervisor for support with managing research data appropriately.

Parents & Children usability trial study

Goal: gather feedback from children (who are key stakeholders) about the usability of the "Fill in the World" game and collect ideas about taking this project forward for conducting a study about gamification impact on intrinsic motivation.

Collected data:

- quantitative data – technical error logs and children's interaction logs.
- qualitative data – feedback about what children liked, what they disliked, and what could be added, changed, or removed.

Setup before meeting:

1. Find a tablet, smartphone, or laptop (besides the device we are calling on, let us call these "game device" and "call device").
2. Make sure both have enough battery.
3. Make sure there is an email address app on the game device.
4. Get their email address and add to user to DB.
5. Change server time to be 7 days before today.
6. Setup the workshop world in DB.

At the start of the meeting:

1. Login on their behalf and they should get an email on the game device with a login link (they do not need to request the login themselves, unless they want to do it again after the study)
2. They can click the link to open the game.

Tasks:

1. Open the game link and try clicking through the World Book.
2. Open the world called "workshop".
3. There is a whole mess of various tools on the ground! Let us clear up the mess by picking up all the objects and putting them in one pile.
    a. Press on an item to see what it is called.
    b. Long press on an item until it turns green and then you can drag it somewhere.
    c. Drag some of the items in a pile.
    d. Now, delete all the items you can see.
    e. Exit the workshop world.
4. Look at the badges in the World Book and find the Tree badge. Read what you must do to earn it. Me or a parent can help to understand the instructions.
5. Make a new world with any name you want.
6. Choose a background for this world.
7. Open the world item list to see what different trees there are.
8. Add 5 different trees to get the Tree badge.
9. Exit the world to see the Tree badge.

Questions after the tasks:

- Can you tell me something that you liked in Fill in the World?
- Can you tell me something that you disliked in Fill in the World?

- Have you played any other language learning games?
    - What did you like/dislike about them?
- Have you played any games like Fill in the World?
    - What did you like/dislike about them?
- Can you tell me any words that you learned by playing today?
- Was the amount of work you had to do to get the badge too little, too much, or just right?
- If you designed a badge yourself, what would it be?
- Is there anything you would like to add or ask about?

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