

# Oppidum

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### **Abstract**

In the late Latène period during the Iron Age, town-like settlements formed the so called Oppida Culture. The Celtic inhabitants made these settlements flourish by trading with Mediterranean people and becoming experts in crafting weapons and working tools that even yielded them the envy of the Romans and Greeks. To teach some of their culture and everyday life, the game Oppidum was created, combining the immersive and entertaining character of Augmented Reality, the charming elements of a board game, and educational methods to ensure an enjoyable learning outcome. Players of this game, with its now enhanced and new features will build and manage their own Celtic village (exonym: "Oppidum") that is full of historical facts, quiz wars, and culture interwoven with aesthetically pleasing Augmented Reality buildings, diverse quests, and victory points.

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# 1 Introduction

## 1.1 Objective

The concept for this game was created in the practical lab course Serious Games, in which a game was developed that combines a learning outcome about Celtic Cultural Heritage with the engagement and entertainment of playing a game supported and enhanced by Augmented Reality. The objective of this project was to refine and extend the game Oppidum, in which one player fights against the computer or two players compete against each other in building their own village, harvest resources, and fight against each other while learning about Celtic life and culture. The enhancements are introduced in Chapter 4.

## 1.2 Serious Educational Games

The term Serious Game (SG) is broadly used in connection with training and simulation, or talking about Serious Educational Games (SEG). These terms also refer to games for education, designed for computers or gaming consoles [1]. Another definition can be drawn from Michael and Chen (2006), which describe SEG as an alternative method of learning [2]. Hereby, the actual learning process of players and their gain in positive affective and cognitive experience is promoted [2]. Therefore, the goal of a SEG is on one hand to support learning, by facilitating the process, and on the other hand, to maximize enjoyment while playing the game [3]. According to Ar Rosyid et al. (2016), the development of a SEG involves two key components - *knowledge space* and *game content space* [4, 5]. Here, the knowledge space covers the learning materials while the transmission of those materials is covered by the game content space [3]. This structuring provides "a higher degree of control" [3] for the game producers.

## 1.3 Augmented Reality

In 1994, Milgram and Kishino introduced the reality-virtuality continuum and described it as the range between real and virtual environments, including Augmented Reality (AR) which is close to the real world and Augmented Virtuality (AV) being close to the virtual environment [6], as shown in Figure 1. Here, the span between Real and Virtual Reality (VR) is defined as Mixed Reality (MR) [6]. AR was later defined as "a system that combines real and virtual content,

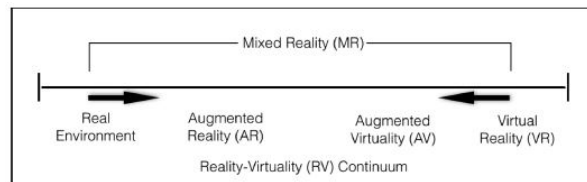


Figure 1: Simplified representation of a reality-virtuality continuum [6]

provides a real-time interactive environment, and registers in 3D” [7], which was recently described as ”Augmented Reality’s most accepted definition” [8] by Bekele et al. The last decades shifted the definition of AR from a system that is not replacing reality but rather completing it [6] to ”a system that enhances our view of the real world by adding virtual and computer-generated information” [8]. Bekele et al. shaped their definition by summarizing sources like Rolland and Fuchs (2000) [9], Vlahakis (2001) [10], Liarokapis et al. (2005) [11], Haydar et al. (2011) [12], and Casella et al (2013) [13] while extracting three characteristics out of them. First, an AR system combines objects from the real and virtual world [7]. Second, it runs in real time, and third, enables the user to interact with virtual objects [11]. Accompanying the addition of virtual objects, Azuma also states the possibility to remove real world objects by overlaying them with virtual ones [7].

Finally, Bekele et al. provides distinct definitions for AR, AV, VR, and MR:

- AR ”aims at enhancing our perception and understanding of the real world by superimposing virtual information on our view of the real world” [8],
- AV ”aims at augmenting the virtual world with scenes from the real world” [8],
- VR ”aims at enhancing our presence and interaction with a computer-generated environment without a means to interact with or see the real world” [8], and
- MR ”aims at blending real and virtual environments” [8].

In conclusion, AR is more deeply connected to real world environments instead of virtual ones and, therefore, only *augments* reality [6], creating a new reality, which is richer in information than the original [14].

## 1.4 Cultural Computing

Cultural Computing (CC) covers ”the application of computer technology in the field of culture, arts, humanities, or social sciences” [12], and accordingly also cultural heritage. Even though the computability of culture is not clear [15], it is still a way to translate culture by using a scientific approach to represent the core aspects of a culture [16]. Haydar et al. (2011) uses another definition of CC by comparing it to a computer technology that can ”enhance, extend, and transform human creative products and processes” [12].

## 1.5 The Goal

Following the earlier definitions of Serious Educational Games and Cultural Computing, the game Oppidum aims to combine these elements in an immersing and entertaining way to support the learning outcome of the players. One side, the games main goal is to be a Serious Game. As such, it needs to transmit Celtic Cultural Heritage and Awareness in a historically accurate way.

The existing game introduced in Chapter 3 uses digital replicas of Celtic building forming a historical reconstruction of an exemplary settlement that could have been build in the Latène period. It also raises Cultural awareness by including historically accurate information into the game elements like quest cards, technologies, and more as well as their visuals without trying to be intrusive. This combination also raises heritage awareness as their buildings were modelled after archaeological finds [17]. As a Serious Educational Game, it uses educational strategies like quizzes and exploration as elements to motivate players to learn and also memorize the content.

On the other side, the learning material is transmitted in an immersive way, using the entertainment of the game as basis and including Augmented Reality as a visually pleasing factor to support the motivation of users to play the game. Furthermore, it aims to use the competition of player and opponent to encourage the users to learn by their own will and thereby increase the learning outcome. The constant need to draw new quest cards (See Chapter 3) brings additional variety into the game in order to keep the player interested.

In the end, the game tries to give players general knowledge and also spark further interest in an entertaining and supportive way. This project therefore aims to endorse these main goals by augmenting the learning outcome with a new learning method and keep the game content itself historically accurate. It also improves the accessibility of the game to a broader target group, that fits the current home office times without trying to take away from the board game and digital hybrid. Eventually, to support all this, the project also intends to create an even more entertaining space where players can better enjoy their learning time and immerse in Celtic times.

## 2 Related Work

### 2.1 Chem Dungeon

Chem Dungeon is a SEG, in which a player needs to walk through a maze (see Figure 2) and find the hidden exit. Inside their shield, the player carries an atom, whose information they can open in a menu bar at the top of the screen, along with a periodic table. In Figure 2 the orange objects are enemies, that the player should avoid, as well as incorrect atom objects. However, they can gather the yellow bullet objects seen in the same illustration to use as ammunition to shoot an enemy, or an atom, which both change location afterwards. Otherwise, colliding with one of them, the player loses a life. If they meet an atom that can form a compound with the one in their shield, an educational message appears that states information about the compound which the user should memorize and the exit is revealed. In addition, the player gets an information box at the top corner holding the last tried compound connection [3]. Chem Dungeon aims to "deploy the learning materials seamlessly and effectively into game content" [3]. The goal was to exploit educational resources like syllabi to produce knowledge chunks and their connection. This was done to be able



Figure 2: Exemplary Chem Dungeon games of different difficulty levels (from left to right: easy, medium, and hard) [3]

to create an educational game without having to consult educational experts and finding the links between the knowledge space and the game content space. As the knowledge space, the game itself offers 100 chemical compounds built of at least two chemical atoms in the form of, for example, "2 Hydrogen and 1 Oxygen construct an H<sub>2</sub>O (water)" [3] which, as a goal, should be memorized by the players. As there is no correlation between compounds, Ar Rosyid et al. supposed that the higher the complexity of each compound is, the higher the difficulty to remember it [3].

As their game content space, they used a rogue-like maze to prevent the players from making a connection between locations and learning materials as seen in Figure 2. Every player received a "consent form, demographic form, practice (training) session and pre-game exam (randomly chosen learning materials)" [3]. For every difficulty level, players had to fill out another questionnaire aimed at the fun/enjoyment experience and a post-game exam.

In general, 50 players generated 540 reports, of which an analysis showed that about 35% did not enjoy the game. Ar Rosyid et al. suppose that different players perceive cognitive experience differently when faced with the same stimuli but also due to a concept drift [18] which changes the affective experience over time.

In terms of learning outcome, by comparing pre- and post-exams, results showed that in sessions where players memorized most materials, it took an average of 15 seconds per player to read the successfully collected compounds information, while in sessions where players did not memorize many materials, the average time of reading compound information was on average 3 seconds. Also, by comparing learning outcome and affective experience, people who enjoyed the game also scored higher in learning [3].

## 2.2 ChiKho Educational Web Game

The ChiKho Educational Web Game is similar to a hurdle-path game made for users who are currently exploring cities as tourists or users who want to explore them at home. Here, players experience a sequence of stages per city with multiple trials in each stage [19]. Every trial game is either based on observation,

reflection or action. ChiKho intends to "promote a credible experience, not a virtual trip disjointed from reality" [19]. In order to allocate the game for home users, the information regarding the city was transmitted in documents, accessible over the web or optional methods implemented in the game like translators. Each game gives players points, not based on time, but rather who completes the game best. For example, a puzzle game would measure how many steps were needed so solve the puzzle while a memory puzzle would record the minimal amount of rounds one would need to remove all cards. The exception are action type games, where the efficiency is actually measured with time. Teams compete against each other by comparing their point results and are not allowed to communicate while playing, but are able to talk outside of the core of the game with the help of a chat messenger.

Belotti et al. concluded after their testing phase, that the people who scored higher were the ones who used the optional tools to improve their performance.

### 2.3 Dragon Tale - A Kanji Game

Dragon Tale is a Serious Game created as a student project in 2016 as an Educational Game. As such, it aims to teach its players Japanese Kanji characters by leading the player through a story where the main character has to find their pet dragon's tribe. To advance in the game, new dialogues have to be unlocked by battling against other characters. While battling, the player has to chose Kanji letters from a dictionary and redraw them. The pet dragon then reacts to the drawing with a corresponding attack.

The game also offers a few minigames that support the learning outcome. One of them consists of a Kanji letter that slowly fades from the monitor and has to be redrawn after it fully disappears. In another minigame, the player has to connect a Kanji letter with the fitting meaning.

In general, the whole game is played on a tablet, using touch input as movement and action control, but also to write the Kanji [20].

### 2.4 Capture the Flag

In the 2015 paper "Capture The Flag: Engaging In A Multi-Device Augmented Reality Game" [21] Mueller et al. presented a multi-device AR game specifically targeted towards being a social experience more akin to a board game. While doing so, they try to incorporate as many aspects of commercially available Android devices as possible to elicit whether or not they will be fun in this setting.

Every player has their own Android smartphone and the playing field is a big Android tablet. The game functions thus: the player uses their smartphone to focus on the playing field and use the various tested actions to move through the game (please see the list below for these actions). As such, while playing the game the user interacts primarily with their personal device to reveal the map and move towards the flags, and only with the playing field when they're stealing the flag. The tablet interaction was chosen, because it was important



that every user noticed this action and also to garner a higher feeling of playing a communal game with each other as opposed to playing alone.

The tested actions a player can take to move within the game are:

- tapping on the game board point on the smartphone screen the user wants to move towards,
- using buttons to move in the respective direction,
- using the smartphone camera to to move in the direction it points, and
- for quicker movement, using the tapping method while blowing in the device’s microphone.

While analyzing the last movement option Mueller et al. found out, that while this option is still “manageable, the addition of more features could very well make it too much for a player to handle in such a quick round” [21]. As such, you have to be careful not to overload the user with too much device interaction at one time.

For this particular game they had some issues with regards to the AR component (on the playing field) as the quick rounds often caused the players to lose tracking of the markers. Their solution was to move the playing field closer to the players. Mueller et al. also discussed the benefits of a real time vs. turn based game, and the mechanics of laying traps on the field.

## 2.5 Learning cultural heritage by serious games

Mortara et al. [22] propose that cultural heritage games (or: serious games) can be split regarding their learning objective, genre, and application context. While a single game genre has not been singled out through the categorization of 52 serious games, both the learning objective and the context can further be broken down. Mortara et al. provide many serious game examples for all of these categories and their respective subcategories.

The learning objective can be split regarding its cultural/educational significance in three ways: cultural awareness, historical reconstruction, and heritage awareness. These three educational objectives are defined like this:

- cultural awareness is “particularly focused on immaterial heritage, including the language, customs, traditions, spiritual beliefs, folklore and rules of behaviour in a society” [22],
- historical reconstruction has “history as the primary educational goal and focus on the faithful reconstruction of a specific historical period, event or process which happened in the past” [22], and
- heritage awareness offers “an immersive, realistic reconstruction of a real location to appreciate and learn the architectural, artistic or natural values of a site, or simply offer engaging mechanisms to motivate users into a real experience” [22].

A game's context means two things, first, whether the game is played in a formal or informal setting (context), i.e. whether it is played for fun or as part of a study, and second, where it is played. The location aspect can for example be: if it is played at home or somewhere public (school, historic sites, etc.). Based on this analysis Mortara et al. then provide an outline on how to create an "engaging learning environment" [22].

## 2.6 Scientific Research

In 2018, Bekele et al. introduced a survey of different kinds of enhanced realities for Cultural Heritage [8] taking into account multiple studies over the last decade that demonstrated the viability of adopting AR in different application areas of Cultural Heritage such as Chrysanthi et al. (2012) [23], Kang (2013) [24], Pietroni et al. (2013) [25], and Basranti et al. (2015) [26]. In their Survey, Bekele et al. state, that there is a need to classify Cultural Heritage Applications to understand where i.a. AR can offer a successful solution and listed the areas "education, exhibition enhancement, exploration, reconstruction, and virtual museums" [8]. Furthermore, they use the insights of Gargalakos et al. (2011) [27] who discussed how "playful learning can cross boundaries among schools, museums, and science centers" [8] by involving participants in multiple episodes of digital interaction. They concluded that playful learning improves learning outcomes as well as increasing curiosity and eagerness to use new technology to gain knowledge.

# 3 Existing Project

## 3.1 Audience

Oppidum is a turn-based hybrid of digital Augmented Reality game and physical board game elements. It is aimed at people with at least a rudimentary background in the usage of smartphones, possibly also AR as certain aspects of the game might be hard to understand otherwise. Players have to understand English, and work with an Android device, so very young non-native speakers and very old people might have problems with the game.

Knowledge about the cultural/historical background of the game is not necessary, as the game aims to teach this content.

## 3.2 Genre

The game is a Serious Educational Game with Augmented Reality aspects, and real live ("board game") components. Concerning its gameplay it can be categorized as a strategy/puzzle game as it contains build-up aspects and quiz games (for a more detailed description of the concrete gameplay please see Section 3.5). It aims to teach the player about Celtic culture.

### 3.3 Educational Objectives

As previously listed in Section 2.5 educational aspects of a game can be divided into cultural awareness, historical reconstruction, and heritage awareness [22]. Oppidum as serious game covers all of these.

Cultural awareness is raised for example by the written information concerning buildings and the like ultimately culminating in the questions asked by the quizzes at different points in the game. Historical reconstruction given by describing different processes like the production of coal in written texts. Heritage awareness is provided by the faithfully reconstructed 3D buildings provided by the AR aspect of the game.

### 3.4 Platform and Used Tools

The existing Project uses a variety of different tools and frameworks both custom build for this project as well as external ones. In general, the project was build in the 3D Unity [28] game engine version 2019.2.11f1. The game is deployed to android devices even though it technically could be deployed to other platforms as well. The mobile and AR capability aspects of a mobile phone or tablet allow Oppidum to use AR to enhance the game experience. For the AR side of Oppidum, Vuforia [29] is used to track markers on the physical cards. Vuforia is an AR platform to easily integrate AR in projects and it delivers a Unity plugin that allows precise tracking and easy integration in the Unity framework. The Server connection and synchronisation is accomplished with the use of a custom framework named Ubi-Interact[30]. It syncs the players with the servers and plays a big role in the way the game manages scene changes and other events that need to be synchronous on both devices.

### 3.5 Gameplay

Each player starts with one side of an empty game board which is seen through an aerial perspective with the help of their Android smartphone or tablet. The game is turn-based having two action points every turn. However, both players play at the same time, so every player participates in every turn and then waits for their opponent to complete theirs. In every turn, players can spend their action points however they like, either by constructing a building, starting a quiz war, unlocking new technologies or later on visit the druid. The actions can also be skipped which leads to a bonus in production for the next round. At the beginning, users get a hint, that they have to build their own settlements by putting markers on the board.

The game can be won by earning 7 victory points. These can be achieved by beating the opponent in objectives like "Most buildings", "Most technologies" or simply winning more quiz wars.

### Buildings and Technologies

The game offers 8 different buildings: "Stable", "Coal Kiln", "Bakery", "Field", "Woodchopper", "Mine", "Druid" and "Forge". Each of them can be built by using the respective marker and paying its building conditions (resources). These conditions are displayed the screen if a player scans the marker and touches the building hammer. When a construction is finished, it produces resources every round, these can in turn be invested in new buildings or in upgrading an existing building's technologies. Every building shows a replica of how the Celtic building most likely looked like as seen in Figure 3. By holding



Figure 3: Building and Replica from inside and outside [17]

the camera near the marker, players can look inside the buildings as the roof becomes transparent. Inside, the interior is also replicated and multiple objects can be found that, if touched, may show information about it. Also, rune stones are hidden inside the buildings that can be collected by touching them and later be used in the druid building.

The position of each building also tracks with its neighbors. Some buildings affect each other if they are closer together and if the product of one buildings is used in the production of the neighboring one's resources. If a player wants to switch positions they can initiate a switching phase after using up all action points. As the fields on the game board are arranged so that two buildings can be placed near to each other, the distance can be tracked by scanning both markers.

If a completed building is touched, the players can also develop more Technologies. Here, a building upgrade window opens up, showing the possible upgrades, how much they cost and how they improve the production. For example, if a player wants to upgrade their field to have a plow, they need to pay 20 woods and 10 tools but gain a 1.5 times higher production rate of crops.

## Druid

The druid has a special building, where you can cast spells with the help of four runes. These runes have to be found inside the buildings and are collected in a rune book that is accessible at the druid's building. By combining 4 found runes in the spell page, the druid can cast a spell that either supports the player's own production or hinders their opponent's. However, the effects of the spell are only becoming effective if the following druid quiz containing only Rune and Druid related questions is won by answering two out of three questions correctly.

## Quiz War

A similar competition to the Druid's happens when one player uses one of their action points to start a quiz war. After both players ended their turn the war starts and both players get 6 random questions out of a question pool to answer. Wrongly answered ones are highlighted in red while correct ones turn green. The one who answers most of the questions correctly, receives a victory point immediately.

## Quests

After an initial beginners phase of five rounds, the players have to draw two shared quest cards. Each quest comes with an informational text whose information can be part of a quiz war question, the fulfillment conditions, the round limit, and penalty conditions. An example for one such quest can be found in

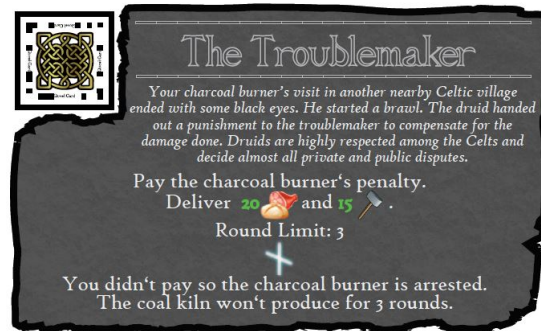


Figure 4: The Quest Card "The Troublemaker"

Figure 4. Here, the players have to deliver 20 food and 15 tools in at maximum three rounds or they will be punished. Their charcoal burner is arrested so their coal kiln won't produce for 3 rounds. If players do not have a charcoal kiln, they will receive no punishment. From round five on, two quest cards have to be active at all times. If one has reached its limit or is fulfilled, another has to be drawn at the beginning of the next turn. This is visualized by a notification to

every players screen and none of them can proceed until the marker in the top left corner is scanned and started.

### **Multiplayer vs Singleplayer**

In Singleplayer mode, the user simply builds their own settlement at their own pace and wins when they reach 7 victory points. When a war is started as a single player, they can only win if they answer more than half of the questions correctly. This means, that in the druid quiz version, they still have to answer two out of three correctly, whereas in a quiz war, they need four out of six right answers.

In the Mutliplayer mode two players have to join the same game via a server connection first. They take their turns simultaneously and a new turn is only started for both players, once both are ready. The victory points from the quiz war are only awarded to the player with the most correct answers. Victory point conditions are shared so that only one player can get a victory point at the same time.

## **4 Approach**

Taking a look at the existing project, there are some points that needed working on and whose changing were set as outcome goals, starting with a way to introduce the game mechanics. The existing version did not have a tutorial that would have explained new players how the game works, what the winning conditions are and how to navigate in the menu. Implementing a tutorial system was thus set as the first goal by the team. Furthermore, the game was designed as a board game and AR combination, which needed both players to be physically present while playing. This works fine, as board games are usually played in that way. However, in times of home office and a pandemic, the game needed a version in which it could be played together without the need to be physically present. Therefore, the second goal was to introduce a multiplayer component that can be played with an internet connection and can also be evaluated from a distance. Also, as Oppidum is a Serious Educational Game, it did contain a lot of information already, but not much educational methods besides monitoring the gained knowledge by having quiz and druid wars. As a game that also tries to teach knowledge, the implementation of more methods was set as the third goal. This goal correlated with another issue that players are faced with inside the game. As Oppidum is a Serious Game, the discrepancy between Celts and the usage of Runes was a subject that needed working on. Also, the way of learning and memorizing the writing system was basic and offered potential to be remodelled.

During the working period of this course, another goal formed, as the AR part of the game supports the immersion of the player by having a modern graphic, which supports the motivation of the players, as seen in the Chem Dungeon example introduced in Chapter 2. This immersion is needed to keep the game

fun. Therefore, another goal was to integrate more mini games into the game to make it even more appealing to players but not disturb its original purpose to transfer knowledge.

#### **4.1 Team Members and Roles**

The team consists of three members, and each member had a significant role in the development process. Every member was already familiar with Unity, Android implementation, and serious games in general, but none had scientific experience with Celtic culture itself or its historical background. However, not being experts on Celts offered the opportunity to analyze how well the existing game transferred knowledge and where the learning process was lacking. By this, the goals of this course were set early in the process as well as the distribution of the main roles. As a conclusion, Katharina Sadzik decided to work on the tutorial and introduction part, Michael Schlicker on the adaptation and evaluation of the game as an online multiplayer, and Andrea Müller on the conversion of the Runes into an Ogham system and development of a learning oriented way to include them. At a later point in the implementation, Katharina Sadzik and Andrea Müller further worked on two ways to integrate a integration of mini games that had a working usage of the phone and also extended the game with further learning materials.

#### **4.2 Introduced Tools**

A framework was introduced that allows to collect player choices and analyzes the decision they made. The framework consists of multiple components that do not depend on each other. The first one is the data collection.

The framework allows easy collection of single data points and aggregation of the data into a bigger picture with automatic assigning of the data to one specific player without using personal data except for the ones used for evaluation of the experience. The data is sent on multiple points during a normal game to ensure the collection of as much data as possible without having to save all of it on the device and still be able to allow a player to pause and resume a session. When data is sent it is first converted to JSON and sent to a Google form[31] as an input of a field. The answers are then converted to a Google sheets[32] file automatically by Google and then imported to a Google Colab[33] for evaluation. This approach allows maximum flexibility while still being easy to set up and cheap to maintain.

During the evaluation step, Python with Pandas[34] in Google Colab was used, to read and format the data as well as make queries on it. After the data is analysed the results are printed with matplotlib[35] built into Pandas.

#### **4.3 Tutorial and Hint System**

In the old version the game's tutorial was handled purely by offering the players hints on what to do with each new round. Here, the user had to intuitively tap

on the pulsing question mark leading (as seen in Figure 5 in the upper right hand corner) to the hint screen themselves, as this was not discussed in the introduction text. Completely new players of the game can find this system lacking, mostly working out the rules of the game themselves by trial and error. For the purpose of an easier game experience a new tutorial system decoupled from the existing hint system was implemented. The hint system now functions purely as a guide through the user interface, although it might be expanded into a more helpful system as discussed in Section 6.

The new tutorial now includes pop-ups throughout the game (see Figure 5). It first appears in the earliest round of the game, telling the user a short background of what the game is about and then telling them how to interact with the real world components of the game. After the user has constructed their first building, the user interface is explained (as can also be referenced at any time in the hint system). When the user ends their first round the last of the general tutorial dialogues appear showing the user what else can be done after all of their action points have been spent. The next tutorial the user sees



Figure 5: Example of a tutorial start page

depends on whether they build the druid or reach round five first. In the fifth round the real world component of quest cards and how to interact with them is introduced. However, if the user builds and interacts with the druid first, there is an introduction on how to interact with the "spell" system (please reference Section 4.5 for the new Ogham system).

Each tutorial dialogue also includes the ability to skip the tutorial (shown in Figure 5), to avoid showing returning players repeat information. If the user skips any tutorial step, the following steps will also not be shown.



## 4.4 Online Multiplayer

Because of the current situation, multiplayer needed to be online with an online collection of usage data as well as information about the user experience. This was accomplished by multiple steps. The first one was the improvement of the tutorial and the reduction of the reliance on the physical items. The next one was allowing online multiplayer. This was straightforward as the networking framework was already enabling online multiplayer. The backend was hosted on an AWS lightsail [36] Ubuntu machine with a static IP address that can then be used to log into any multiplayer game if both players enter the IP address in the menu. To start the backend on an online server it needs to be uploaded, for example with SFTP first and then started via SSH. After all Node.js packages are installed the backend can be started like any Node.js project. The last step was the collection of the usage data via the cloud, as well as moving the physical questionnaire to a digital form.

## 4.5 Ogham System

Replacing the so far used Runes inside the game, an Ogham system was introduced in an effort to increase the Serious Game factor of the game.

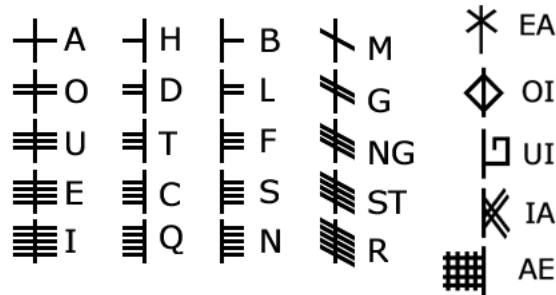


Figure 6: Ogham tree alphabet [37]

The Ogham system consists of intricate markings that rise from the lower left up to the center and then down to the lower right and forms a tree alphabet known as Ogham. Each letter has a unique combination of kind of line and amount of lines, as seen in Figure 6. Throughout the buildings that can be displayed when scanning markers, the player can now find Ogham stones (see Figure 7) with Ogham words on them, instead of single runes. These stones are spread through every available construction and disappear when clicked on. Whenever one of them is found, a message appears that the player is able to access a new word by visiting their druid. The initial rune book was replaced by a Dictionary (see Figure 8) in which the words are now stored, together with their Latin translation and can be accessed through the Druid building. Here,

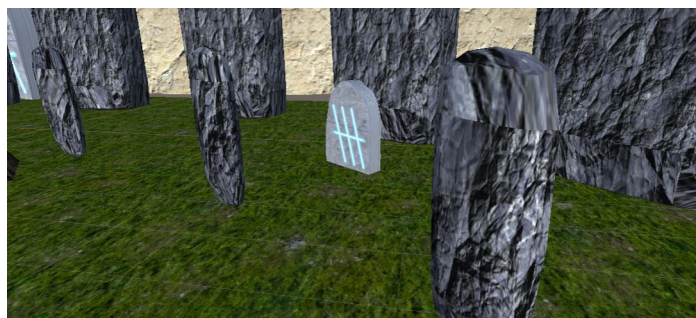


Figure 7: Exemplary stone that can be found in the game

the collected words are displayed and can be memorized there, if wanted. Every word that can be found in the game consists of 4 letters so every word has the same length. This change was made in an effort to include a more historically set



Figure 8: The Dictionary

of characters but also to give a meaning when combining single letters instead of just assembling single runes without reason. This way, the player has the chance to combine characters to actual letters and words in their head. This was decided with the introduced Kanji Game in Chapter 2 in mind, where the combination of the word fire and a fire attack lead to a better learning outcome as users could form a connection that could be remembered more easily.

When a player visits their city's Druid, instead of performing spells, they can now write words consisting of four Ogham letters. In Figure 9, an empty writing page can be seen.

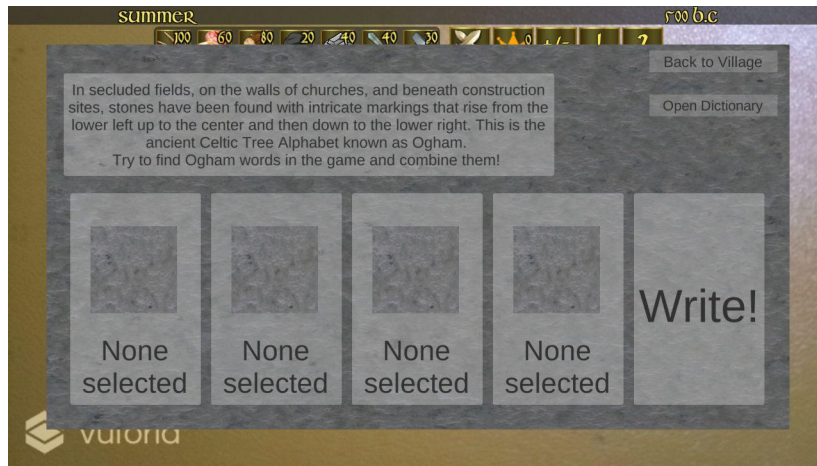


Figure 9: Empty Writing Page

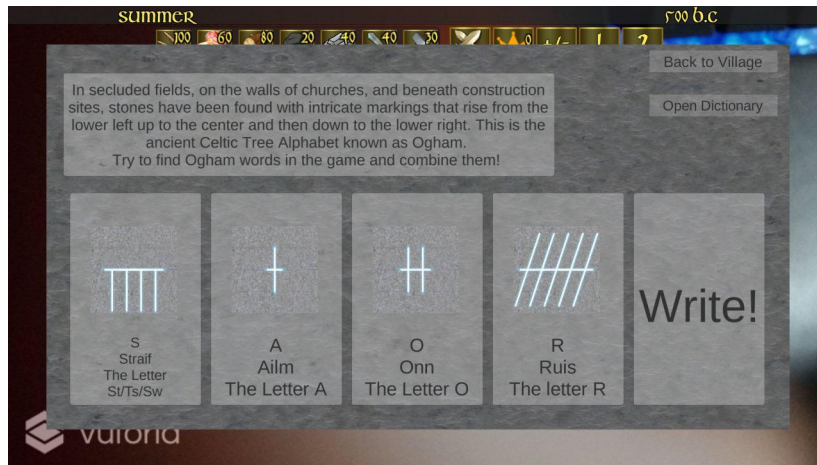


Figure 10: Filled Writing Page

When touching one of the empty slots, a drawing space appears where the user can draw lines to write an Ogham letter one by one. To present a better visualization for the player, the lines are adjusted after their finger leaves the screen to form a straight line. If the letter is drawn correctly, it is filled into the chosen spell slot. Otherwise, the slot stays empty. An exemplary drawing can be seen in Figure 11. The image shows the letter R in the Ogham system. The Ogham letter system uses depictions that are not unique, which means that the combination AO would be written the same as U. As the display of a tablet or even a smartphone is rather small, especially when writing with the finger and a whole word that can be in the worst case four times five lines long

(IQNR), the user is only allowed to write one letter at a time. Also, if the user writes one letter wrongly they do not have to start from the beginning again. In addition, by writing only one word and then returning to the writing page, the user can access the dictionary in between and check how the word is written, as the memorization process is checked in the druid war after the writing.

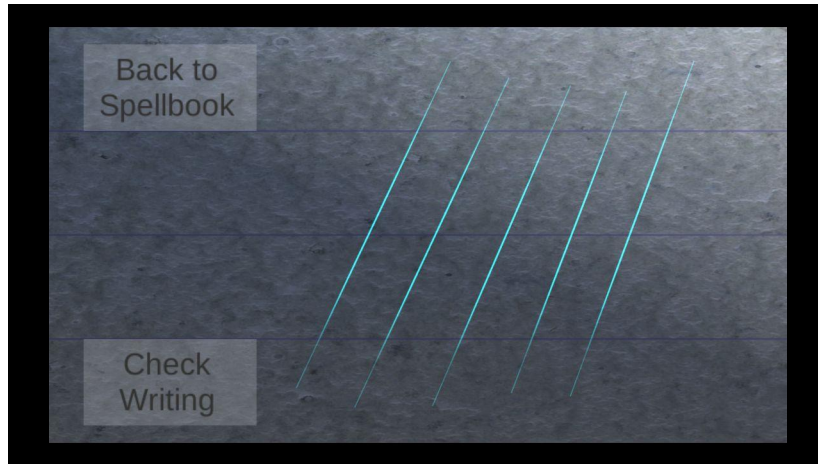


Figure 11: The user has written the letter R

If all writing slots are filled and the word exists, as for example seen in Figure 10 at the bottom, the player can press "Write!" and is led to a druid quiz consisting of druid related questions where they have to answer two out of three correctly. If they succeed, they see the outcome of the spell. The example given in Figure 10 would turn out as in Figure 12. As every word consists of four

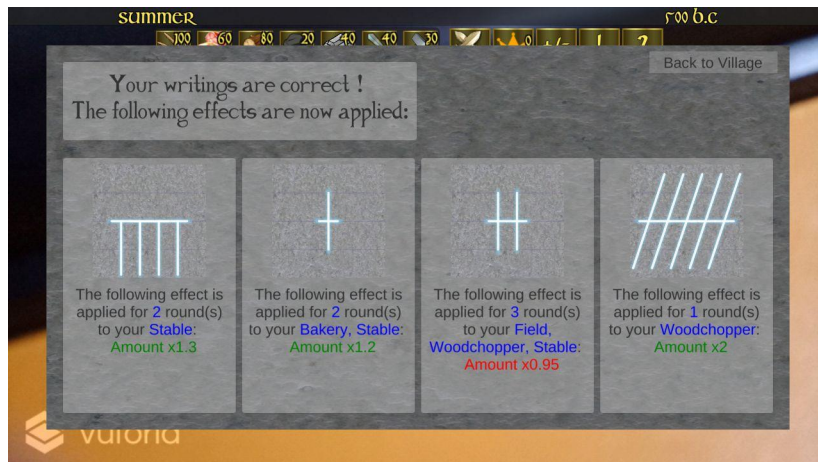


Figure 12: Outcome of a successful spell

letters, four effects are applied. These can be either an amplification of your own harvest of resources or a minimized harvest of your opponent. Here, this system was inherited by the initial version.

## 4.6 Android Integration

As seen in Chapter 2, one way to improve learning in a serious game with AR is by making the players learn playfully. Motivated by this insight, two methods of integrating the phone in an entertaining way were implemented.

### 4.6.1 Accelerometer

During the game, the player has to construct buildings that, after a few rounds, are finished constructing. Initially, the buildings just appeared after finishing construction. Thus, a player only had to pay its construction materials and come back later. Now, when the player returns to see its building, the construction is hidden behind a stone plate until they shake the device to break through the stone (see Figure 13). Only after breaking it, the building can be used.

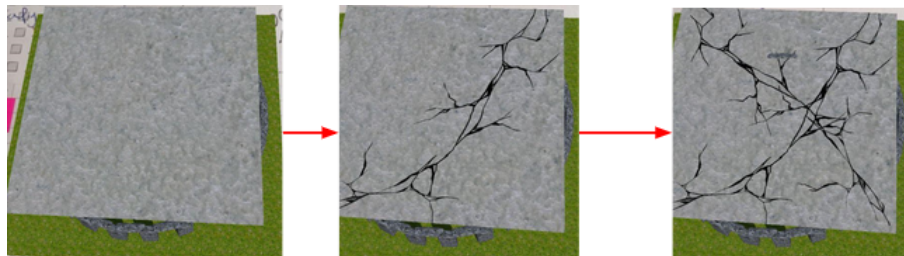


Figure 13: Breaking of the stone plate in its three stages

Here, the accelerometer of the Android device recognizes the acceleration while shaking and breaks the stone when a certain threshold is met. In the end, the user has to break the stone three times, meaning they have to meet that threshold multiple times, to break the whole stone. Each break is displayed with a breaking animation, so the user can see their progress.

### 4.6.2 Microphone

As another addition of how to better integrate more possibilities of using the Android OS, Oppidum now offers a way to use the microphone to imitate a flute. This also fits well with Celtic culture as musicians (bards) were held in high regard.

Bards, i.e. minstrel-poets, existed in many cultures, e.g. Germanic, Hunnic, and also in Celtic culture. These bards would entertain guests at feasts with heroic songs, sung praise for the king, and also mocked the host's enemies [38]. During planning, there had been some discussion about whether to use a flute



or an ocarina for this task as both would fit in the time period with the first primitive flutes found dating back 35000 years [39] and the first ocarinas dating back over 12000 years [40]. While flutes would be more easily accepted by players as belonging to the time period, ocarinas would be easier to play using big devices like tablets by giving the user two usable gripping points instead of just one. In the end, a flute was chosen to not cause a break in the generally accepted cultural shorthand of the target audience.

This flute is now added to the "Motivate Workers" button. When this button is pressed, the flute screen is shown as seen in Figure 14. Now, when the user presses and holds one of the black buttons on the flute and blows into their devices' microphone at the same time a flute tone rings out. The user can press as many buttons as they wish to play a little melody. Simultaneously pressing more than one button is also supported.

General information regarding bards in Celtic culture can be found by tapping the information button on the flute screen as seen in Figure 14. When the user

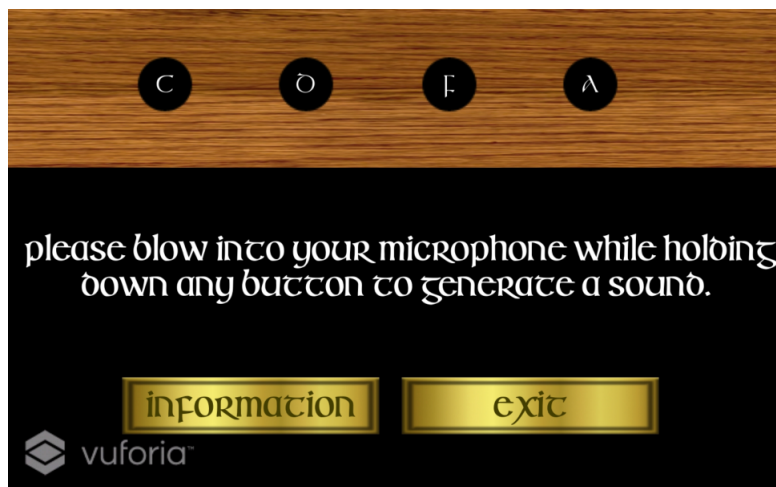


Figure 14: Motivate workers screen

is finished with their melody, they can press the exit button and receive all benefits of the old "Motivate Workers" button. If the user does not wish to play a melody or plays the game in an area requiring quiet, they can also skip this mini game. As such, the user will also not be able to recover their action points by exiting without playing the flute if they accidentally clicked on "Motivate Workers".

## 5 Evaluation

The main option for an evaluation of the knowledge gain of a participant is the use of a knowledge questionnaire at the beginning and the end of each

play-through. By comparing the right answers to the first and second sets of questions the quality of the knowledge gained for short-term memory can be evaluated. Because of the constraints of the current situation the evaluation of the project needed to be done online, not in in-person testing. This resulted in the questionnaire becoming a part of the built project.

## 5.1 Method

To evaluate the player experience for online multiplayer and even singleplayer from afar, player data and experience had to be logged and collected automatically and via online channels. To accomplish this task a questionnaire was introduced at the beginning and the end of every game. These, in combination with recording the actions of the players, are then collected over a cloud service and evaluated.

## 5.2 Testing

The questionnaire consists of the same questions as in [17]. This allows it to be evaluated against older versions of the project and gives a better understanding of the development of the project. For the usage data, a multitude of player choices were collected. The gameplay itself was not recorded. This gains information about player choices without having too much data to analyze. On top of that it reduces privacy concerns. Especially the player choices during the quiz wars give valuable insights in the knowledge gained by a player during the game.

## 5.3 Analysis

After testing with two people, the players experienced a significant knowledge gain as seen in 15. This aligns with previous tests conducted on Oppidum. However, due to the way the evaluation pipeline is structured, these results can be generated automatically. The small sample size is not representative and originates from the current situation which imposes more difficulties to a study. For example, giving physical items to players like the game board. For these reasons a study was not in the scope of this project. A more representative one should be done in the future as explained more in detail in the following section. Nevertheless, it shows that the changes made to the project enabled a way to easily generate those results without manual work to evaluate the results of the questionnaire.

# 6 Future Work

Oppidum's worth is formed by the pillars Serious Educational Game teaching historical awareness and Entertainment supported by AR and Android integration. This project made an effort on deepening these two fields. On one side,

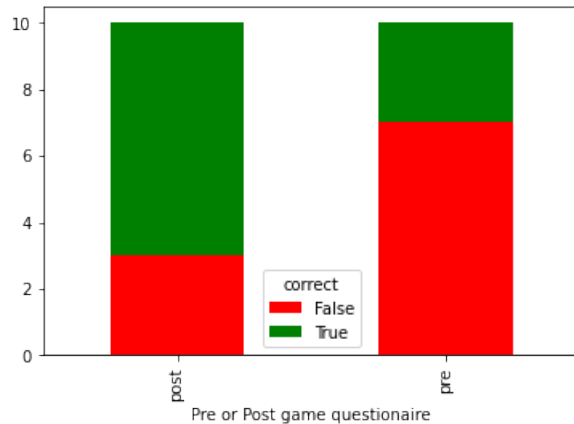


Figure 15: Knowledge Questionnaire Evaluation

the historical awareness was deepened by changing the Runes to an more accurate Ogham system that also teaches to write the letters. Additionally, the presented information that can be found during the game, for example in quiz wars, was extended. On the other side, the usage of the accelerometer and the microphone of the phone that also introduced mini games expanded the fun factor of Oppidum. Furthermore, the game was enabled to be played from home to adapt to the current home office times.

However, all of these points can still be improved.

First of all, the game and its new content needs to be tested extensively to not only have theoretical researched gain but also get a proper feedback of whether the additions are actual improvements. This includes a way bigger testing group and also a control group. In general, it has to be tested, whether the writing systems adds to the learning outcome, possibly by asking people to write a few words they remember. Also, a feedback on how the tutorial helped to understand or which questions were still open after the help system should be evaluated to see if the hints, that the players get supported to understand the rules and intentions of the game. In addition, it makes sense to check, whether people like the home office Multiplayer version more, than the initial offline Multiplayer idea. This testing also affords a solution for the board as Oppidum intends to be a board game AR combination. The board and its markers can be printed and be sent to people by mail or converted into digital form. This could also be decided by a larger testing group, giving one part of them a digital version and the other a physical one and evaluate which group had a better experience. Another point is the competition. Oppidum makes player compete against each other, so motivate them during the game, by making them race to fulfill quest cards first, and of course winning the game. Most Serious Educational Games tend to use cooperation and communication to teach people to learn, in contrast to Oppidum that aims to use competition to urge the players



to learn and memorize information to have better chances to win. If this competitive learning adds up or would be improved could be tested by having two users play the Singleplayer version as a group in contrast to have two players compete against each other and see who learned more and maybe who learned faster.

Second, the evaluation of the extensive tests can then be implemented into the game. The tutorial, for example, could stretch during the whole game, reacting to players that are stuck, or that are currently having a significantly less amount of victory points than their enemies. This would keep the players motivated, by not falling back to much and still having a chance. Regarding the competitive character of the game, it could profit from more interaction with your opponent, especially if people are not playing in the same room but from home. There needs to be a solution on how people can communicate during the game, possibly by introducing a chat or maybe voice communication. Also, currently a player cannot see how many victory points your enemy currently has or how many buildings they have already constructed. This could be integrated into the hint system by telling the opponent whenever you build a house or gained a victory point.

As seen in the game Chem Dungeon in Chapter 2, Serious Games profit from an immersing and entertaining game as a fun experience supports the learning outcome heavily. Therefore, the taken steps of using the accelerometer and microphone of the smartphone could be improved. For instance, the motivate workers flute could be extended into a rhythm game that, depending on how well one played, could give either a trophy or random resources. Another effect of mini games can be achieved by taking them even further by making them part of every turn, possibly with varieties in how to use them or random mini games when one player has to wait for the other player as every turn is synchronized. Oppidum also uses AR for immersion and heritage reconstruction. Both can be combined by implementing new buildings or simply a mini game marker. Also, the communication can partly be controlled over a statue that, for example, shows a unfinished statue that finishes a bit more every time the opponent earns a victory point. Another version could be that the statue builds up every time the player themselves earns a point and thereby functioning as a trophy. The statue parts itself could then be infused with more historical information or give access to more mini games.

Another improvement can be taken from the Kanji Game of chapter 2. Here, the game and the motivation for moving on an thereby learning more Kanji was heavily influenced by the story. Players who wanted to progress in the story had to memorize more Kanji and also were given a meaning on why they should learn. Introducing a story line that adapts to building houses and having progress could augment the players interest even more and could also be used as a reason to move on when the game is played in Singleplayer mode. One way to implement a story is to construct a narrative of a special settlement and its flourishing growth. After the players construct a building, for example a bakery, and ending their turn, the narrative could include the happened events by showing the players another page in the narrative, for instance a diary. This

entry could contain the current year and season, and retells how the owner of the diary experienced the construction of a bakery and from then on their settlement fed on tasty bread. The story could be reread on a book marker, which would then serve as a time filler or trophy again. Furthermore, the book can also be used as another way to tell historical facts and information.

At last, as the game is mostly an educational game, there need to be more ways to integrate actual learning methods. At the moment, the only used methods are memorizing by finding written information during the game, writing actual letters than just selecting them, and rechecking the acquired knowledge in the war and druid quiz. More ways could be by using techniques from the ChiKho Game, described in Chapter 2. Here, the users were given the opportunity to search for information themselves with the help of an integrated search engine. As this would give the players in a competitive game an probably unfair advantage, Oppidums version could be a Notebook, where people can write down information they have found on a small space, forcing them to summarize the information or building memory hooks.

## 7 Conclusion

Eventually, regarding the initial weak points of the existing project, the new version of Oppidum introduced suggestions to fix these. The newly implemented functions were chosen based on scientific research by comparing results of prior projects of similar game approaches and their strong points.

Overall, the rune system was exchanged with the historically likelier Ogham system, that allows the player to write the letters themselves and thereby having a higher learning outcome, than by simply clicking on them. This change, as well as the additional integrated historical information in the quiz and druid wars, support the cultural awareness (see Section 2.5) of the Serious Educational Game that Oppidum intends to be.

Furthermore, the current home office dependant times afforded an easier and more accessible way of using the Multiplayer at home. The outcome of Oppidum now allows users to play together without the need of meeting physically. This is supported by the adoption of the tutorial and hint system, as this enables users to play without the need of an introduction by an expert as well as future project members to understand the game and its rules without having to figure out themselves what the game is supposed to do and how it is supposed to be played. This way, the game is able to be used and tested and improved in the future as well.

At last, this project also took an effort in adding to the entertainment factor of the game by introducing Minigames and combining them with Android tools and Augmented reality output in order to add to the fun that the Oppidum players need to experience to achieve a better learning outcome.

With this project, the stepping stones of further work and of course of ongoing playability were set by improving the pillars "Serious Game" and "Entertainment" that form Oppidum but also showing the way on where and how it can

be evolved even further.

## Bibliography

- [1] Tarja Susi, Mikael Johannesson, and Per Backlund. Serious games - an overview. 11 2015.
- [2] David Michael and Sandra Chen. Serious games: Games that educate, train, and inform. 01 2006.
- [3] Harits Ar Rosyid, Matt Palmerlee, and Ke Chen. Deploying learning materials to game content for serious education game development: A case study. *Entertainment Computing*, 26:1–9, 08 2016.
- [4] Damir Ismailović, Juan Haladjian, Barbara Köhler, Dennis Pagano, and Bernd Brügge. Adaptive serious game development. GAS '12, page 23–26. IEEE Press, 2012.
- [5] A. Hussaan, Karim Sehaba, and A. Mille. Tailoring serious games with adaptive pedagogical scenarios: A serious game for persons with cognitive disabilities. *2011 IEEE 11th International Conference on Advanced Learning Technologies*, pages 486–490, 2011.
- [6] P. Milgram and F. Kishino. A taxonomy of mixed reality visual displays, 1994. *IEICE Transactions on Information Systems*, Vol. E77-D, No.12 Dec. 1994.
- [7] Ronald T. Azuma. A Survey of Augmented Reality. *Presence: Teleoperators, Virtual Environments*, 6(4):355–385, 1997.
- [8] Mafkereseb Kassahun Bekele, Roberto Pierdicca, Emanuele Frontoni, Eva Savina Malinverni, and James Gain. A Survey of Augmented, Virtual, and Mixed Reality for Cultural Heritage. *ACM Journal on Computing Cultural Heritage*, 11(2):36, 2018.
- [9] Jannick Rolland and Henry Fuchs. Optical versus video see-through head-mounted displays in medical visualization. *Presence*, 9:287–309, 06 2000.
- [10] Vassilios Vlahakis, John Karigiannis, Manolis Tsotros, Michael Goumaris, Luís Almeida, Didier Stricker, Tim Gleue, Ioannis Christou, and Nikolaos Ioannidis. Archeoguide: first results of an augmented reality, mobile computing system in cultural heritage sites. pages 131–140, 01 2001.
- [11] Liarokapis, Fotis and Greatbatch, Ian and Mountain, D. and Gunesh, Anil and Brujic-Okretic, Vesna and Raper, J. Mobile augmented reality techniques for geovisualisation. volume 2005, pages 745– 751, 08 2005.
- [12] Mahmoud Haydar, David Roussel, Madjid Maldi, Samir Otmame, and Malik Mallem. Virtual and augmented reality for cultural computing and heritage: A case study of virtual exploration of underwater archaeological sites (preprint). *Virtual Reality*, 15:311–327, 11 2011.

- [13] Guida Casella and Moises Coelho. Augmented heritage - situating augmented reality mobile apps in cultural heritage communication. pages 138–140, 07 2013.
- [14] Tomáš Jeřábek, Vladimír Rambousek, and Radka Wildová. Perceptual specifics and categorisation of augmented reality systems. *Procedia - Social and Behavioral Sciences*, 191:1740–1744, 06 2015.
- [15] Fei-Yue Wang. Is culture computable? *IEEE Intelligent Systems*, 24(02):2–3, 2009.
- [16] Naoko Tosa, Seigow Matsuoka, Brad Ellis, Hirotada Ueda, and Ryohei Nakatsu. Cultural computing with context-aware application: Zenetic computer. pages 13–23, 09 2005.
- [17] David Plecher, Konstantin Gomm, Christian Eichhorn, and Gudrun Klinker. Impact of Single- and Multiplayer Mode in a Serious-AR-Game for Cultural Heritage of the Celts, 2020.
- [18] Jonathan Roberts and Ke Chen. Learning-based procedural content generation. *Computational Intelligence and AI in Games, IEEE Transactions on*, 7:88–101, 03 2015.
- [19] Francesco Bellotti, Edmondo Ferretti, and Alessandro De Gloria. Discovering the european heritage through the chikho educational web game. In Mark Maybury, Oliviero Stock, and Wolfgang Wahlster, editors, *Intelligent Technologies for Interactive Entertainment*, pages 13–22, Berlin, Heidelberg, 2005. Springer Berlin Heidelberg.
- [20] Katharina Brand, Janosch Kindl, Stefan Kreisig, and Monika Wintergerst. Dragon Tale. A Kanji Game, 2016.
- [21] Suzanne Mueller, Andreas Dippon, and Gudrun Klinker. Capture the flag: Engaging in a multi-device augmented reality game. In *Proceedings of the 2015 International Conference on Interactive Tabletops & Surfaces*, pages 277–282, 2015.
- [22] Michela Mortara, Chiara Eva Catalano, Francesco Bellotti, Giusy Fiucci, Minica Houry-Panchetti, and Panagiotis Petridis. Learning cultural heritage by serious games. *Journal of Cultural Heritage*, 15(3):318–325, 2014.
- [23] Angeliki Chrysanthi, Costas Papadopoulos, Tom Frankland, and Graeme Earl. ‘Tangible Pasts’: User-centred Design of a Mixed Reality Application for Cultural Heritage: Papers from the 40th Annual Conference of Computer Applications and Quantitative Methods in Archaeology (CAA), Southampton, 26-29 March 2012, pages 31–39. 12 2014.
- [24] Jiyoung Kang. Ar teleport: Digital reconstruction of historical and cultural-heritage sites for mobile phones via movement-based interactions. *Wireless Personal Communications*, 70:1443–1462, 2013.

- [25] Eva Pietroni, Alfonsina Pagano, and Claudio Rufa. The etruscanning project: Gesture-based interaction and user experience in the virtual reconstruction of the regolini-galassi tomb. pages 653–660, 10 2013.
- [26] Sara Gonizzi Barsanti, Giandomenico Caruso, Laura Micoli, Mario Covarrubias, and Gabriele Guidi. 3d visualization of cultural heritage artefacts with virtual reality devices. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XL-5/W7:165–172, 08 2015.
- [27] M. Gargalakos, E Giallouri, Angelos Lazoudis, Sofoklis Sotiriou, and Franz Bogner. Assessing the impact of technology-enhanced field trips in science centers and museums. *Advanced Science Letters*, 4:3332–3341, 11 2011.
- [28] Unity. <https://unity.com/>, 2020. [Online; accessed 21-October-2020].
- [29] Vuforia. <https://www.ptc.com/en/products/vuforia>, 2020. [Online; accessed 21-October-2020].
- [30] Ubi-Interact. <https://wiki.tum.de/pages/viewpage.action?pageId=190677154>, 2020. [Online; accessed 21-October-2020].
- [31] Google Forms. <https://www.google.com/forms/about/>, 2020. [Online; accessed 21-October-2020].
- [32] Google Sheets. <https://www.google.com/sheets/about/>, 2020. [Online; accessed 21-October-2020].
- [33] Google Colab. <https://colab.research.google.com/>, 2020. [Online; accessed 21-October-2020].
- [34] pandas. <https://pandas.pydata.org/>, 2020. [Online; accessed 21-October-2020].
- [35] matplotlib. <https://matplotlib.org/>, 2020. [Online; accessed 21-October-2020].
- [36] Amazon Lightsail. [https://aws.amazon.com/lightsail/?nc2=type\\_a](https://aws.amazon.com/lightsail/?nc2=type_a), 2020. [Online; accessed 21-October-2020].
- [37] Ogham.Co. Ogham Transliterator. <https://ogham.co/wp-content/uploads/2018/02/the-ogham-alphabet.png>, 2020. [Online; accessed 20-October-2020].
- [38] Alexander Demandt. *Die Kelten*, volume 2101. CH Beck, 2007.
- [39] Pallab Ghosh. 'Oldest musical instrument' found. <http://news.bbc.co.uk/2/hi/science/nature/8117915.stm>, 2009. [Online; accessed 18-October-2020].
- [40] Ocarina History. <https://web.archive.org/web/20150330215941/http://ocarinaforest.com/info/history/>, 2013. [Online; accessed 18-October-2020].

## A Appendix Questionnaire

Question	possible Answers
What is your gender?	Male Female Prefer not to say
How old are you?	Free Text
How experienced are you with video games?	Options from 1-7
Identify your player type at <a href="http://matthewbarr.co.uk/bartle">http://matthewbarr.co.uk/bartle</a> and enter the abbreviation provided in the result page (e.g. "EKAS")	Free text
I frequently play video games [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I frequently play board games. [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have used games before as a means to learn [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have experience with Augmented reality applications [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I am interested in early european history. [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have general knowledge about early european history. [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have general knowledge about Celts [strongly disagree (1) - (7) strongly agree]	Options from 1-7
How familiar are you with the Celts?	I've heard of them I have a general idea who they were I know about their life and history I know details and facts
When did Celts of Iron Age approximately live?	1200BC-400BC 800BC-0 200BC-500AC 400AC-1200AC
How did the majority of Celts live?	They were mostly nomads They lived in Celtic villages and fortified settlements Distributed in cities of greater nations of that time They lived in huge Celtic cities
Name two important trading goods exported by the Celts.	Free text
Mark all terms that correspond to traditional festivals of the Celts	Fehu Beltaine Imbolg Sowilo Easter
What was the Celts' primary way of obtaining food?	Hunting and Gathering Agriculture Raiding Trading
How confident are you about the correctness of your answers of the "Questions about the Celts" section? *	Options from 1-7

Table 1: Pre-game Questionnaire

Question	possible Answers
I felt capable while playing the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I grasped the overall goal of the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The game was not too easy ant not too hard. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
Playing the game was meaningful to me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I was no longer ware of my surroundings. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The goals of the game were clear to me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
Playing the game was valuable to me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt I was good at playing this game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The game felt relevant to me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
It was easy to know how to perform actions in the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt a sense of freedom about how I wanted to play this game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The challenges in the game were at the right level of difficulty for me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The challenges in the game were at the right level of difficulty for me. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I enjoyed the way the game was styled. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The actions to control the game were clear. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The game gave clear feedback on my progress towards the goals. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I wanted to explore how the game evolved. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The game was challenging but not too challenging. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I understood the objectives of the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I thought the game was easy to control. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt eager to discover how the game continued. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
The game informed me of my progress in the game [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt a sense of mastery playing this game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt free to play the game in my own way. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I was immersed in the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I wanted to find out how the game progressed .[strongly disagree 1 - 7 strongly agree]	Options from 1-7
I liked the look and feel of the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I felt like I had choices regarding how I wanted to play this game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
I was fully focused on the game. [strongly disagree 1 - 7 strongly agree]	Options from 1-7
When playing Oppidum, did you feel more like interacting with a "game environment" or a "learning environment"? [learning environment 1 - 7 game environment]	Options from 1-7



Question	possible Answers
I am interested in early european history. [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have general knowledge about early european history. [strongly disagree (1) - (7) strongly agree]	Options from 1-7
I have general knowledge about Celts [strongly disagree (1) - (7) strongly agree]	Options from 1-7
How familiar are you with the Celts?	I've heard of them I have a general idea who they were I know about their life and history I know details and facts
How did the Celts settle most private & public disputes?	The chieftain decided A jury decided The druid decided A judge decided
What was the Celts' primary way of obtaining food?	Hunting and Gathering Agriculture Raiding Trading
When did Celts of Iron Age approximately live?	1200BC-400BC 800BC-0 200BC-500AC 400AC-1200AC
Name two important trading goods exported by the Celts.	Free text
How was Celtic leadership organized?	They had no organized leadership Ruled by a king from a central place Ruled by a rich chieftain per principedom Ruled by one commonly elected leader
How did the majority of Celts live?	They were mostly nomads They lived in Celtic villages and fortified settlements Distributed in cities of greater nations of that time They lived in huge Celtic cities
Name two trading partners of the Celts	Free Text
Mark all terms that correspond to traditional festivals of the Celts	Fehu Beltaine Imbolg Sowilo Easter
What did the Celts use their iron for? (name two)	Free Text
How did the Celts bury their dead?	In round grave hills In lakes and rivers Burnt in huge funeral fires In deep caves
How confident are you about the correctness of your answers of the "Questions about the Celts" section? *	Options from 1-7
What do you think about games as a learning platform? Would you play games like Oppidum in your free time?	Free Text
Did Augmented Reality improve the game experience for you?	Free Text
Did you especially like something?	Free Text
Do you have suggestions for improvement?	Free Text
Anything else?	Free Text

Table 2: Post-game Questionnaire