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Impacts of Serious Games for Cultural Heritage

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TECHNISCHE UNIVERSITÄT MÜNCHEN

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Vollständiger Abdruck der von der Fakultät für Informatik der Technischen Universität München zur Erlangung des akademischen Grades eines

Doktors der Naturwissenschaften (Dr. rer. nat.)

genehmigten Dissertation.

Vorsitzender:
Prof. Dr.-Ing. Jörg Ott

Prüfende der Dissertation:
1. Prof. Gudrun J. Klinker, Ph.D.
2. apl. Prof. Dr. Georg Groh

Die Dissertation wurde am 24.02.2021 bei der Technischen Universität München eingereicht und durch die Fakultät für Informatik am 08.04.2021 angenommen.

Meinen Eltern

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Abstract

Serious Games combine the world of playing games for entertainment with the world of learning. The player acquires new knowledge almost subconsciously, but it is not a simple task to turn this theory into practice. Combining the two worlds also requires meeting the demands of both. On the one hand, the learning content must be presented correctly and coherently, but on the other hand, it must be perfectly integrated into the game world. This concerns both the presentation and the application of what has been learned in the game. Serious Games have great potential, which has not yet been used enough due to the difficulties mentioned above.

Three different Serious Games were implemented on the topic of tangible as well as intangible cultural heritage, which will be presented in the course of this thesis. Through appropriate studies with corresponding questionnaires, the respective effects of the Serious Games were investigated, especially regarding their knowledge transfer.

The first game is *DragonTale*, a story-based single-player Serious Game, which among other elements uses augmented reality (AR) to facilitate the introduction to the Japanese language, especially the learning of Kanji including their meaning, correct notation and the ability to combine them. To investigate the influence of AR, two variants of the game (with and without AR) were evaluated with two test groups.

Furthermore, *Oppidum*, a Serious-AR-Game about the history and culture of the Celts, was implemented. By using AR, classic board game elements are combined with digital gameplay. Historically accurate 3D models of Celtic buildings provide the player with information about the tangible cultural heritage of the Celts. A study examined the impact of single- and multiplayer on knowledge transfer through two different test groups.

As the third Serious Game, *HieroQuest* is introduced. Here, the player is taught hieroglyphs in the form of an escape game and is also given insights into Egyptian intangible cultural heritage by incorporating one of the oldest recorded stories of mankind - the *Story of the Shipwrecked Sailor*. Several studies were conducted during the iterative development process. In addition to gaming-experienced attendees, students of Egyptology participated in the main study. As a consequence, it was possible to look at the effects of the game on players with different levels of prior knowledge.

It was shown that all three Serious Games have a positive impact on knowledge transfer, hence they can make a valuable contribution to the conveyance of information about cultural heritage.

Kurzfassung

Serious Games verbinden die Welt des Spielens zur Unterhaltung mit der Welt des Lernens. Idealerweise erlangt der Spieler fast schon unbewusst neues Wissen. Was sich in der Theorie einfach anhört, ist realiter nicht so einfach umzusetzen. Die beiden Welten verbinden zu wollen, erfordert auch den Anforderungen beider gerecht zu werden. So muss einerseits der Lerninhalt korrekt und in sich stimmig abgebildet, andererseits aber perfekt in die Spielewelt integriert werden. Dies betrifft sowohl die Präsentation als auch die Anwendung des Gelernten im Spiel. Serious Games haben ein großes Potential, welches bisher aufgrund der angesprochenen Schwierigkeiten noch zu wenig genutzt wird. Es wurden drei verschiedene Serious Games zum Thema materielles sowie immaterielles Kulturerbe implementiert, welche im Zuge dieser Arbeit vorgestellt werden. Durch geeignete Studien mit entsprechenden Fragebögen wurden die jeweiligen Effekte der Serious Games insbesondere in Bezug auf den Wissenstransfer untersucht.

Das erste Spiel ist *DragonTale*, ein storybasiertes Single-player Serious Game, welches unter anderem Augmented Reality (AR) Elemente einsetzt, um den Einstieg in die Japanische Sprache insbesondere das Erlernen von Kanji inklusive deren Bedeutung, korrekter Schreibung und Kombinierbarkeit zu erleichtern. Der Einfluss von AR wurde durch zwei Varianten des Spiels (mit und ohne AR) mit zwei Testgruppen evaluiert.

Des Weiteren wurde *Oppidum*, ein Serious-AR-Game über die Geschichte und Kultur der Kelten, implementiert. Durch den Einsatz von AR werden Elemente aus klassischen Brettspielen mit dem digitalen Spiel verbunden. Historisch akkurate 3D Modelle keltischer Gebäude vermitteln dem Spieler Informationen über das materielle Kulturerbe der Kelten. In der Studie wurde zudem mit zwei verschiedenen Testgruppen der Einfluss von Single- und Multiplayer auf den Wissenstransfer untersucht.

Als drittes Serious Game wird *HieroQuest* vorgestellt. Hier werden dem Spieler in Form eines Escape-Games Hieroglyphen gelehrt und zusätzlich durch Einbeziehung einer der ältesten Geschichten der Menschheit – der *Geschichte des schiffbrüchigen Seemanns*– Einblicke in das ägyptische immaterielle Kulturerbe gegeben. Während des iterativen Entwicklungsprozesses wurden mehrere Studien durchgeführt. An der Hauptstudie nahmen neben Teilnehmern mit Spielerfahrungen zusätzlich auch Studenten der Ägyptologie teil. Dadurch konnte betrachtet werden, welche Effekte das Spiel auf Spieler mit unterschiedlichen Vorkenntnissen auswirkt.

Es konnte gezeigt werden, dass alle drei Serious Games einen positiven Einfluss auf den Wissenstransfer haben und somit einen wertvollen Beitrag zur Vermittlung von kulturellem Erbe leisten können.

Prior Publications

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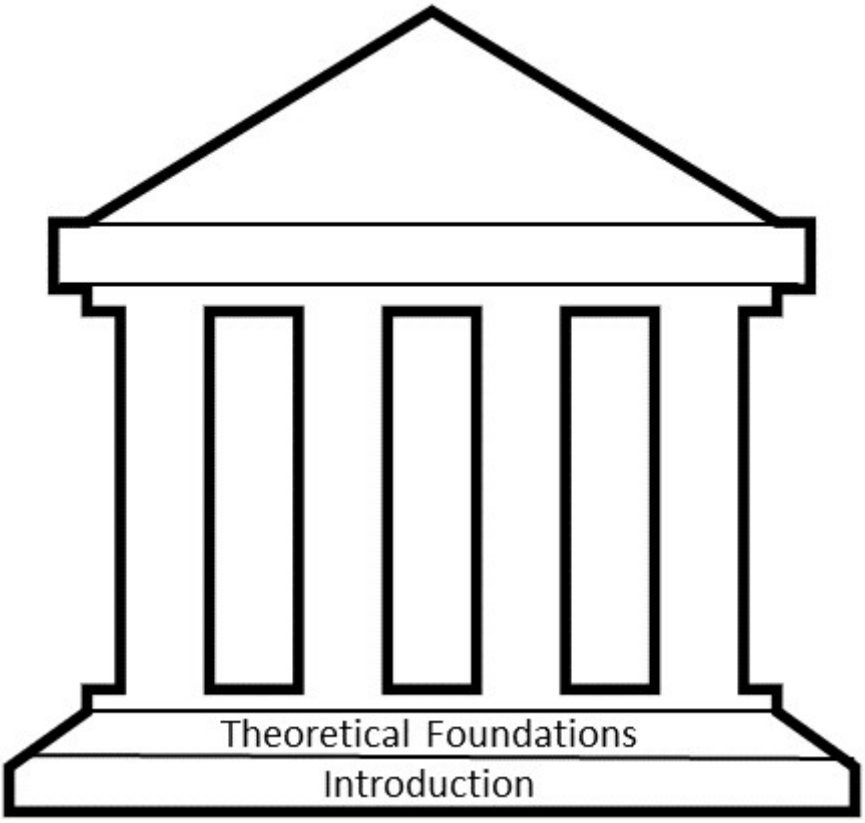
Contents

Part I.

Introduction and Theoretical Foundations
(Base, *crepidoma*)



1. Introduction

"παίζειν δ' ὅπως σπουδάζῃ"

"Play so that you may be serious."[1] These words are ascribed to Anarchasis, who was a Scythian philosopher and lived about 600 BC. This very short phrase describes already the dichotomy between games and seriousness. According to the quote the diversion that comes along while playing is a form of rest, which is absolutely essential for humans, because they are not made for continuous work. In ancient Greece, playing is not associated with learning, development or improvement. Rather, the principle "πάθει μάθος"[2] applies: learning happens only through great effort or literally through suffering. Until today, games have a slightly negative connotation and are associated with unproductiveness or even increase of aggression - ignoring the plethora of merits. An alternative draft are games that can have a positive impact on the players' body and brain. In recent years the term Serious Games took root for this phenomenon. However, the concept is not a new invention. The history of Serious Games is much older than one might think and this is true for both digital and non-digital games. Around the year 475 BC, the game 'weiqi', which we know today as 'Go', was created in Asia to practice military strategy (Halter, 2006). Although chess in its present form is only documented for the 6th century AD in Persia, it is based on much older games from the Indian region. The figures represent the different unit types of the army and also allow the learning of military strategies (Murray, 1913). It is not surprising that the first digital Serious Games also dealt with this topic. These were not intended for the commercial market, but were used during the Cold War to play through various scenarios in order to simulate and analyse military, economic and political decisions together with their respective consequences. One of the first games of this kind was "Grand Strategy" (Abt, 1987). Accordingly, the first-person shooter "America's Army", the first digital Serious Game for private use, followed in 2002 with the aim of arousing the interest of the players and consequently increasing the recruitment rates in the US. It was "the first successful and well-executed Serious Game that gained total public awareness" (Gudmundsen, 2006). This was the start of the so-called "digital renaissance" (Sawyer & Rejeski, 2002), whereupon various non-military disciplines made use of it to transfer the desired content via gaming. Until today it is still a challenge to develop a perfect Serious Game, which is fun to play and has a positive influence on the player at the same time.

[1] Aristotle, eth. Nic. 10,6.
[2] Aesch. Ag. 177.

1.1. Goals and Research Questions

The goal of this thesis is to combine Serious Games and cultural heritage, which can be classified as natural heritage and heritage created by mankind. The latter corresponds to tangible (e.g. monuments and artifacts) and intangible objects (e.g. languages and traditions) (Vecco, 2010). Augmented Reality (AR) has often been used to convey knowledge about tangible heritage, especially in situ. This technique - which is explained in more detail in section 3.3.3 - allows to enrich reality with virtual information (2D/3D) using e.g. cameras and displays. We use AR in two of the Serious Games we will present in this thesis. All games presented in the course of this work are designed to answer the main question:

- **Can Serious Games transfer knowledge about intangible or tangible cultural heritage?**

To this end, different games towards topics like languages, writing systems, history and archaeology were implemented. Each of the Serious Games, which will be presented one after the other, has additional and different research questions.

DragonTale (chapter 5) is designed to help the player get started in learning the Japanese language. It focuses on the transfer of knowledge about Japanese kanji. In addition to a stirring story, attention has been paid to the use of AR to present the knowledge content in an appealing way. The additional research question is in this project:

- **What impact does AR have on the transfer of knowledge in a Serious Game about Japanese Kanji?**

Oppidum (chapter 6) provides information about the life and history of the Celts. It is a construction game that uses AR to present historically accurate 3D reconstructions of buildings, but also much more information about Celtic life. Two consecutive studies were carried out. The last one additionally dealt with the question:

- **What effect does a competitive multiplayer mode have compared with a single-player mode on learning motivation and learning outcomes?**

HieroQuest (chapter 7) is intended to introduce Egyptian hieroglyphs to the player and also to give insights into one of the oldest stories of mankind, the *Story of the Shipwrecked Sailor*. The iterative development process with several pre-studies culminates in a main study with participants from both the Games Engineering and Egyptology departments. The following was also additionally examined:

- **What impact does the autonomous use of a game mechanic have on learning success in a Serious Game?**

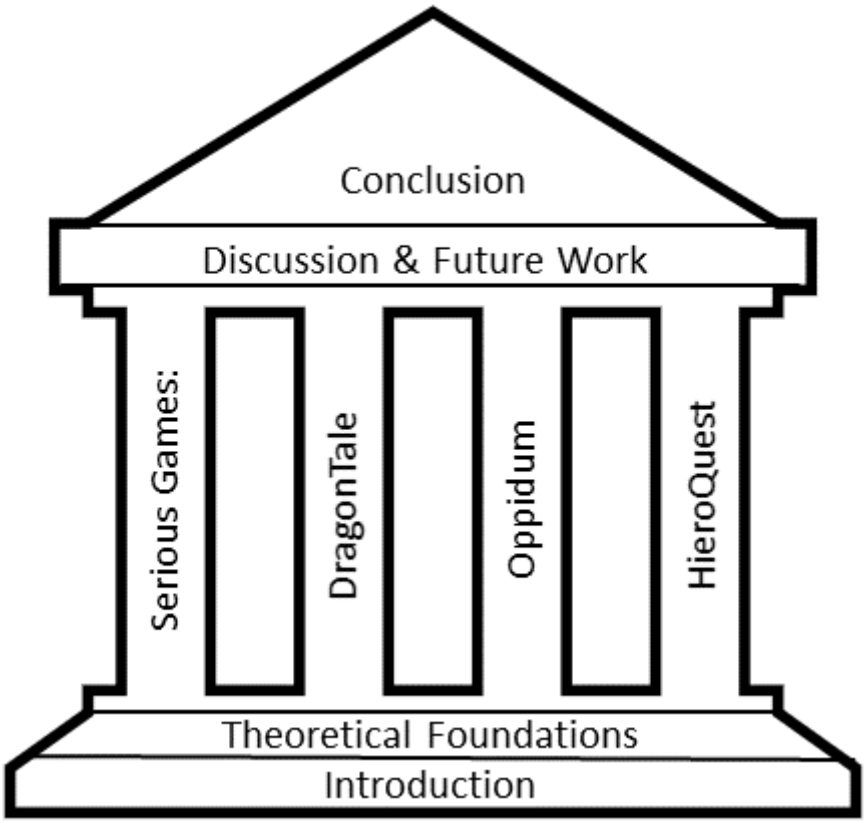


Figure 1.1.: Structure of the thesis

1.2. Overview

This thesis is constructed like an ancient Greek temple (see Figure 1.1). On the base (*crepidoma*) consisting of the theoretical foundations lies the practical part represented by *columns*. Each column corresponds to a Serious Game, which contains a topic from the area of cultural heritage. The discussion of the results, an outlook into future works and a final conclusion of the thesis are the *entablature* of the temple respectively the completion of the work.

Part I: *Introduction and Theoretical Foundations (Base, Crepidoma)*

- **Chapter 1** contains the basic goals and the structure of the thesis
- **Chapter 2** deals with the theoretical foundation of Serious Games. Besides its definition, the basic effects which games of this kind can trigger are considered. The underlying psychological factors and the common game elements are also discussed.

Part II: *Serious Games (Columns)*
The practical part introduces the different projects one after the other. It starts with Serious Games, which transfer knowledge to the player with the help of AR.

- **Chapter 5** The first one is the game *DragonTale*, which was designed for learners of the Japanese language. In a Japanese style game landscape the player follows the story of a girl and a small dragon and learns the most fundamental kanjis (characters). AR is used to reinforce what has been learned and to visualize grammatical peculiarities.
- **Chapter 6** The Serious Game *Oppidum*, which deals with the life and history of the Celts, belongs to the same category. The player takes care of a Celtic village whose houses and buildings can be displayed and inspected in the form of historically accurate 3D models using AR.
- **Chapter 7** The third game is *HieroQuest*, which teaches the player hieroglyphs in the form of an escape game and also gives an insight into the Egyptian culture by including one of the oldest stories of mankind - *Story of the Shipwrecked Sailor*

Part III: *Discussion, Future Work and Conclusion (Entablature)*

- **Chapter 8** Discussion & Future Work
- **Chapter 9** Conclusion

2. Theoretical Background of Gaming

This chapter describes the theoretical principles in detail. This is especially necessary as there are different definitions for the various elements of this thesis. Only by clearly positioning the different concepts in relation to each other it is possible to compare the results of this thesis with others (Clark, 2007). We clarify the important terms and concepts, that will reappear in the following sections. To ensure a common understanding, we define the term *Serious Game* and differentiate it from other terms that describe apparently similar phenomena.

2.1. Serious Games

The term *Serious Games* was introduced by Clark C. Abt in 1970. He chose with intent this oxymoron to show that two different and even mutually exclusive worlds - gaming and learning - were connected in this phenomenon. His research was related to card and board games, hence not digital games, yet his conclusions can be transferred (Abt, 1987). At this point it should be mentioned that the famous board game 'Monopoly' (1935) was also developed to playfully illustrate the influence of monopolies on the economy (Orbanes, 2002). The scope of Serious Games can be simplified to knowledge transfer and behavioral change. There are many terms in circulation that describe similar things but still do not mean the same. Since it is important to explain and to clearly differentiate them, we have to start at the very beginning.

Looking at the term Serious Games, one would assume that the difficulty of understanding is hidden in the first part - the seriousness. This ignores the fact that the word games is not as easy to understand as it seems. What exactly are actual games and is there one common interpretation of this term?

Homo Ludens and the Definiton of Play: Games have probably existed almost as long as mankind. Findings of toys from the stone age and corresponding cave paintings suggest this. The first complex games we know that have fixed rules are the Egyptian 'Senet' and the 'Royal Game of Ur' also known as the 'Game of Twenty Squares' that belongs to ancient Mesopotamia. Both games can be traced back at least to the 3rd millennium BC and are precursors of Backgammon (Piccione, 1980; Tam, 2008). Games have accompanied and even shaped people ever since.

Hence, in 1938 Huizinga refers to human beings as 'Homo Ludens':

"It seems to me that next to Homo Faber, and perhaps on the same level as Homo Sapiens, Homo Ludens, Man the Player, deserves a place in our nomenclature" (Huizinga, 2014).

Let us first consider game and play as synonymous. In the further course of this section we will look at both terms individually and also differentiate between them. In the following we look at the definition of playing in general according to Huizinga:

"Play is a free activity standing quite consciously outside 'ordinary' life as being 'not serious,' but at the same time absorbing the player intensely and utterly. It is an activity connected with no material interest, and no profit can be gained by it. It proceeds within its own proper boundaries of time and space according to fixed rules and in an orderly manner" (Huizinga, 2014)

Therefore, playing creates own worlds for the player and allows him to escape from ordinary reality for a certain time. It should be emphasized that Huizinga explicitly does not consider games to be serious. While Roger Caillois (Caillois, 2001) largely agrees with Huizinga's definition, he criticises the lack of a classification of games. So he introduced the following categories:

- ἀγών **- competition:** The Greek word for competition. The actual term of the Olympic Games in ancient times was Ολυμπιακοί Αγώνες. This is to describe competition as a characteristic of the game; in terms of achieving and solving the challenge or in outdoing the opponent.
- **alea - chance:** Alea the Latin word for dice. It describes chance and thus that part of the game which can not be influenced by the player through special mental or physical skills. In its pure form, this can be found in the casino. However, it can also be used as an admixture, e.g. in card games, where the cards are shuffled and dealt randomly to ensure a fair starting position.
- ἴλιγξ **- vertigo, dizziness:** Certainly the most difficult part of the classification. The Greek term actually means literally whirlpool and is supposed to stand for the disturbance of one's own perception or a kind of ecstasy, such as those that arise when one turns quickly around one's own body axis.
- μίμησις **- mimicry:** Imitation and thus playing a different role. This includes theatre but also childlike play.

2.1.1. Gaming vs. Playing

As already indicated, the deeper study of this topic requires a distinction of playing and gaming. Huizinga (2014) already pointed out the differences in the concept of the game in different languages. The Dutch language *('spelen')* as well as French *('jouer')* or German *('spielen')* know only one term. The English language on the other hand has two different terms for this - 'playing' and 'gaming'. The terms are usually used as synonyms, but they differ on closer examination. Caillois (2001) refers to Ancient Greek and Latin to describe this dichotomy.

Figure 2.1.: The παιδιά-ludus (playing-gaming) - Continuum (Caillois, 2001)

The παιδιά-ludus (playing-gaming) - Continuum (Caillois, 2001): The quote that introduced this thesis uses the verb παίζειν as a term for playing. This includes the word παῖς, which means child. Caillois therefore equates play with παιδιά, meaning the child-like game, which is characterized by its abandonment of rules and focuses mainly on the fun that results from it. Children playfully discover the world. The mimicry, which is part of the taxonomy of Caillois, is especially important here. Children imitate their experiences in everyday life and often playfully take over the role of adults. It should be especially noted that there is no concrete goal and therefore no one emerges as winner or loser. It is played for the sake of playing.

Gaming is equated with the Latin term ludus and represents the other extreme of the continuum. The Romans used this word for any kind of game but also for their gladiator schools *(ludus magnus)* and the Roman primary school *(ludus litterarius)*. In this definition, it stands for the game with strict rules and goals that can challenge the player.

As simple as the distinction between the two extrema may be, the transitions are fluid. Role-play can be used as an example here. We have already considered children's play as imitation of the environment (mimicry) and characterized it as playing or παιδιά. Free role-playing without fixed rules can also have a higher goal. In psychotherapy, replaying certain situations can be helpful in working through negative events. The play itself does not follow any rules and doesn't need a goal, but as soon as the perspective is shifted to an outside view, the play can be analysed for the therapeutic purpose. Likewise, the understanding of two conflicting parties for each other can be better analyzed if their roles are exchanged as soon as the point of view is taken to an outside perspective. Some role-playing can also be classified partly as ludus. If we look at MMORPGs, for example, the player takes on a certain role with the associated abilities and thus follows fixed rules of the game. Here the player still has freedom on basis of given rules, whereas the extreme form of role play can be seen in theater. Taking over and playing a role in a theater play, such as in Shakespeare's Macbeth, can very well be assigned to ludus, since here, of course, both a literary model and a fixed staging are followed.

2.1.2. Defining Serious Games and Gamification

Building on the work of Caillois and Huizinga, it is now possible to look at the individual definitions of Serious Games and also clearly distinguish them from other concepts such as Gamification. Serious Games are very difficult to define clearly, because *"no*

universally accepted definition exists" (Dörner, Göbel, Effelsberg, & Wiemeyer, 2016). Abt defined it as follows:

"The oxymoron of Serious Games unites the seriousness of thought problems that require it with the experimental and emotional freedom of active play. Serious Games combine the analytic and questioning concentration of the scientific viewpoint with the intuitive freedom and rewards of imaginative, artistic arts" (Abt, 1987).

The most modern definitions are based on the fact that Serious Games are more than just entertainment:

- *"A game that doesn't have entertainment as primary purpose"* (Michael & Chen, 2005).
- *"A digital game with the intention to entertain and to achieve one additional goal"* (Dörner et al., 2016).
- *"Any meaningful use of computerized game/game industry resources whose chief mission is not entertainment"* (Sawyer, 2007).
- *"A mental contest, played with a computer in accordance with specific rules, that uses entertainment, to further government or corporate training, education, health, public policy, and strategic communication objectives"* (Zyda, 2005).
- *"Any form of interactive computer-based game software for one or multiple players to be used on any platform and that has been developed with the intention to be more than entertainment"* (Ritterfeld, Cody, & Vorderer, 2009).

As already shown, a Serious Game can be a board game as well as a digital game. It is not a genre but rather a phenomenon (Dörner et al., 2016). Consequently, we believe that the definition should not differentiate between digital and non-digital games. Every Serious Game can be classified as a game, but not every game can be defined as 'serious'. As a consequence, the definition of Deterding, Dixon, Khaled, and Nacke (2011) is selected:

"Serious Games is the use of full-fledged games in a non-gaming context"

This definition draws a clear line between Serious Games and Gamification, which refers to the *"use of game elements in a non-gaming context"* (Deterding et al., 2011). Gamification is often used for customer retention. By buying at certain stores and using appropriate coupons, the user can collect points, which he can then exchange for rewards. The elements of collecting (points) and multiplier (coupons) are borrowed from games. Here, the gambling instinct of the player is addressed and a customer loyalty to the participating department stores, supermarkets, etc. is generated. Sometimes this is also erroneously called an *"Alternate Reality Game"* (McGonigal, 2011), i.e. a game that is played in real life.

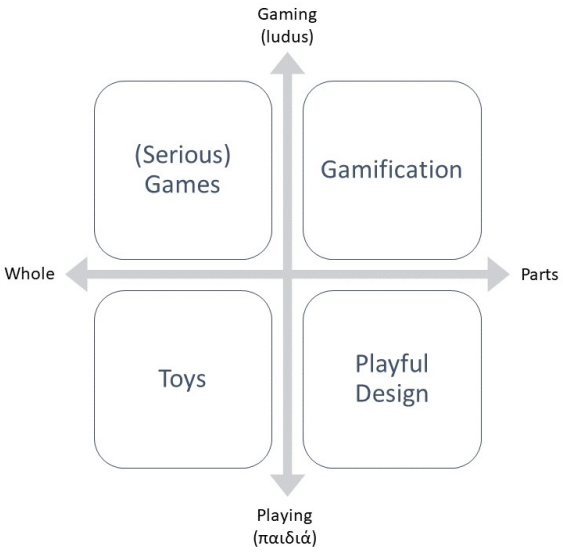


Figure 2.2.: Serious Games and the differentiation from Gamification according to Deterding et al. (2011).

Figure 2.2 summarizes the findings on Gamification and Serious Games. Deterding et al. (2011) use the continuum of Caillois and put it in relation to whether games are used in their entirety or only partially. As vertical axis serves the mentioned separation of gaming and playing. Complemented by the horizontal axis which distinguishes between complete games and parts of them. In quadrants I and II the difference between Serious Games and Gamification becomes clear. Deterding et al. (2011) define Gamification as usage of *"gaming elements in a non-gaming context"*. Consequently, only parts of a game are used including rules and objectives. Analogous to this, Serious Games are defined as *"complete games used in a non-gaming context"*.

Quadrants III and IV symbolize the childish, non rule-based play:

- **Toys** - like dolls or building blocks symbolize the childlike but complete game.
- **Playful Design** - Here, only elements of play are used to attract the attention. The goal is the amusement and an emotional response of the user. One example is the so-called *Fail Whale*. This is a picture of a friendly looking whale lifted by birds. Twitter shows this cartoon in case of an overload on the servers to keep the user informed and in a good mood. (Borges, Durelli, Reis, & Isotani, 2014)

2.1.3. Subgroups of Serious Games

There are different subgroups of Serious Games that are named according to their purpose or to their *"characterising goals"* (Dörner et al., 2016). This can be seen in the following examples:

Educational Games or Edutainment: These games are used for educational purposes. With knowledge transfer they cover one of the major effects of Serious Games and therefore form an important subgroup (Sauvé, Renaud, & Kaufman, 2010). This will be explained in section 4.2 in more detail.

Pervasive Games: A common definition by Montola, Stenros, Waern, et al. (2009) for this genre is: Any game that has *"one or more salient features that expand the contractual magic circle of play spatially, temporally, or socially"*. An essential characteristic is the inclusion of the real world, which is used as a playing surface. Appearances can be role-playing games, but also the use of AR can be part of it, whereby the environment is enriched by virtual objects.

Advergames: The purpose of this subgroup is clearly advertising. This is already evident from the term, as it is a portmanteau made up of the words advertisement and game (Cauberghe & De Pelsmacker, 2010). The previously mentioned game 'America's Army' falls into this category since it was designed to increase the recruitment rates in the US.

Exergames: This is also a portmanteau consisting of exercise and game. This mainly refers to physical exercise. Therefore, the goal of this subgroup is to trigger a change in the player's behaviour (Oh & Yang, 2010). For example 'Pokémon Go' animates the players to go outside and walk certain distances or visit special places to be successfull in the game.

Games with a Purpose (GWAP): There are few examples where the roles of teacher (computer) and learner (player) are reversed (Von Ahn, 2006). The puzzles of the game 'Foldit' (Khatib et al., 2011) are based on real problems with protein chains, which have to be brought into a given shape by folding. The solution strategies of the players were able to surpass the computer-generated algorithms at some points and thus helped to improve them. The game designers are challenged to present the problem in such a way that even players without any previous knowledge of the scientific subject matter can contribute to the solution simply through their ideas and playful talent.

2.1.4. The "Magic" of Serious Games

Perfectly combining the worlds of learning and playing to enable playful learning or learning while playing is like searching for the holy grail. However, before we go into the effects of Serious Games, we must first look at digital games in general. Already the game 'Pac-Man', which gained great fame in the early 80s, fascinated the player. Bowman (1982) describes the game as a "fever", which of course also infects students and apparently has a magical effect on its players, which especially teachers envy.

"[They] have begun to wonder aloud if perhaps the magic of 'Pac-Man' cannot be bottled and unleashed in the classroom to enhance students' involvement, enjoyment and commitment" (Bowman, 1982).

The question was to what extent the effects of the game could be extracted in order to use them in teaching and education. The possibility of integrating teaching or learning content into the game itself was not considered in this case. So let's stay with the investigation of this magic, which comes from 'Pac-Man'. One has to know that this game was first created as an arcade game. The interaction possibilities were hence limited to joystick and a few buttons. Playing was only possible if a coin was inserted before. Therefore, the aim of the developers was to create a game that inspires to generate a long playing time - one could also call it a certain addiction - and consequently a lot of money. So they took care to start with a rather easy difficulty and increase it slowly. Every player should have the opportunity to acquire the necessary skills of control and thus be successful in the game. *"This balancing of game difficulty and player skill was critical to the success of arcade games"* (Przybylski, Rigby, & Ryan, 2010).

This "magic" thus achieves that students deal intensively with a matter for a long time and voluntarily train and improve their abilities. Additionally, it should be mentioned that the game does not bring any material advantage, but rather causes costs. These effects alone already make games interesting for educational use.

Educational Impact of Games in General: Games can do much more than just generate enthusiasm. Obviously, playing games that use a controller or, as in the case of the first 'Pac-man' Games, joystick and buttons as input devices, is also accompanied by learning motor skills. Games in general are also characterized by the fact that they allow the player to train some cognitive and interpersonal skills.
Kirriemuir and Mcfarlane (2004) have collected some of them:

- **Planning and strategic thinking:** First of all it is important to understand the rules and apply them. In a further step the player tries to optimize his playful behavior according to the rules. *Strategic planning* involves not only implementing one's own moves and plans, but also observing and, at best, anticipating the intentions and reactions of other players.
- **Interaction with other players:** Many games encourage interaction with other players in both cooperative and competitive play. This includes joint planning within the group or basic *communication* with all participants. In games that involve

trade or some form of market, communication in connection with the exchange or sale of goods or objects also trains *negotiation skills*.

Prensky (2001) described a phenomenon of knowledge transfer about the games of the 'Pokémon' universe. These are available as card games, classic video games and successful smartphone applications. Another special characteristic can be found especially among the young players. The occupation with these games leads to the fact that the adolescents are able to memorize a very large amount of partly very complicated names of the different monsters including their abilities and stages of development. Consequently, a transfer of knowledge takes place here, which is voluntary and without further reward. This phenomenon must now be further considered in order to both explore the reasons for this and to transfer it for further educational projects with different learning content.

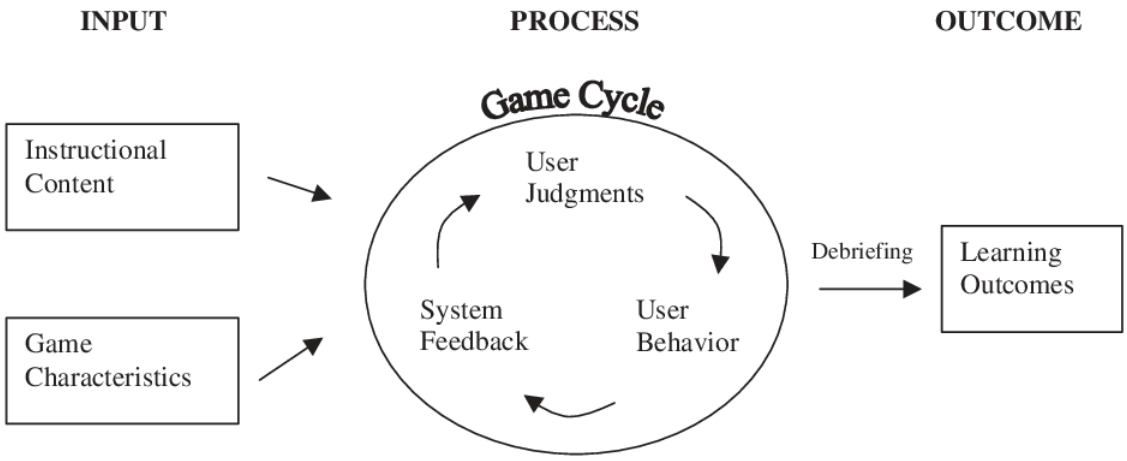


Figure 2.3.: Game Model by Garris et al. (2002): Input-Process-Outcome

The Process of Learning in General: The first question that arises is, how does a person actually learn? Even in the ancient world people tried to find answers to this question. Plato, for example, assumed that the human soul already carries all knowledge within itself. Consequently, learning would be the process by which humans rediscover the knowledge that is already within them. It is therefore also called the "doctrine of recollection".
Modern research distinguishes human learning by means of three different theories, each of which refers to the learning process (Hinojosa et al., 2015):

1. **Behaviorism:** According to this theory, learning of certain behavioral patterns occurs through observation and imitation. The learner assumes a passive role and reacts to appropriate stimuli (actio-reactio or stimulus-response). The learner's behavior is shaped by positive and negative reinforcement. This is also called

conditioning. In this case the teacher, who represents a role model is of great importance. The learning content must be explained precisely and step by step. (Skinner, 1965)

2. **Cognitivism:** In this theory the learner assumes an active role. New information is processed by comparing and analyzing it with the existing knowledge in memory. This generates new knowledge, which can be retrieved with the appropriate stimulus (information retrieval). The learning content should be prepared both acoustically and visually for better processing. (Woolfolk, 2012)

3. **Constructivism:** In this case new knowledge is generated solely from already known knowledge. The learners can access their own memory, but can also use the stored information of other people by interacting with them to build new connections. The role of the teachers is on the one hand to make their knowledge available and on the other hand to accompany and guide the construction process. (Woolfolk, 2012)

The Process of Learning in Games: As has been shown, games teach motor, social and cognitive skills. Since these games like 'Pac-Man' or 'Pokémon' are actually designed for entertainment, the skill developments can be considered as side effects. To develop Serious Games, it is important to understand how these effects are caused by playing. Garris et al. (2002) illustrates this in an Input-Process-Output Model (see Figure 2.3). In the center of this model is the so-called *Game Cycle*, which is run through again and again by the player while playing. To create this cycle, a Serious Game needs game characteristics and instructional or learning content. We will analyze this input in more detail later. Both together interwoven in a Serious Game are the basis for running through the *Game Cycle*, which in turn is responsible for the *Learning Outcome*. How does this *Game Cycle* work? An action of the player (*User Behavior*) leads to an evaluation by the game mechanics in the form of direct feedback from the system (*System Feedback*). The player in turn evaluates this reaction (*User Judgment*) and adjusts his further game behavior. Positive feedback on correct behavior and appropriate solutions, corrections or criticism of mistakes lead to a learning effect (*Learning Outcome*). A well-designed Serious Game enables *"to transform game events into learning experiences"* (Garris et al., 2002).

2.1.5. Motivation

Before we address the individual factors, it is important to examine and understand the driving force that makes the player go through the mentioned *Game Cycle* over and over again.

Motivation is the decisive factor. A person is driven by motives (lat. movere). Even Aristippos of Cyrene, a disciple of Socrates, identified the hedonistic principle as the drive for human action. People try to reach the state of joy (ἡδονή), but avoid problems

and pain. The state of joy is different from fun, much more in this case it denotes the holistic feeling of happiness or well-being. However, this is only one side of the motivation theory. There are two basic types:

- **Extrinsic Motivation:** The human behaviour is directed towards a goal which is given from the outside (lat. extrinsecus). This can be a financial advantage *(instrumental motivation)*, the fulfilment of external expectations *(external self concept)* or the adoption of the goals of others *(goal internalization)* (Barbuto Jr & Scholl, 1998).

- **Intrinsic Motivation:** In this case human action is determined from within (lat. intrinsecus). It is not subject to any external compulsion and therefore happens voluntarily *(intrinsic process)*. As in the hedonistic principle, here joy outweighs other advantages of any kind. It is also possible that man has created an image or model for himself which he pursues *(internal self concept)*. (Barbuto Jr & Scholl, 1998).

What is the more desirable type of motivation?: Experiments in the 1940s by Harlow, Harlow, and Meyer (1950) investigated intrinsic motivation or the so-called "third drive". This is an action that is neither caused by satisfying basic needs nor by reward. Harlow provided eight rhesus monkeys with a simple mechanical puzzle. To his surprise, they learned to solve it of their own accord within a short time and improved their strategy over the days.
"The performance of the task provided intrinsic reward" (Harlow et al., 1950). When the same experiment was repeated, the monkeys were rewarded with raisins for each successful solution of the puzzle. The introduction of this extrinsic motivation led to an overall deterioration. More mistakes happened and the general interest in the task decreased.

20 years later Edward Deci (Deci, 1971) conducted a similar experiment with human participants. They had the task to solve three different Soma cube puzzles on three consecutive days. During the experiment, Deci left the room for eight minutes after the second solved puzzle under a pretext and observed whether the participants were busy with the last puzzle or reading one of the intentionally laid out magazines. The participants had previously been divided into two groups. Group I completed the described scenario the same way every day without rewards and used on average half of the waiting time for the last puzzle. In contrast to group II, which received $1 for each correct solution on the second day. The payment was left out on the last day with the following consequences. While in group I the results of the individual days hardly differed, group II showed more commitment on the second day due to the monetary reward. So, they were occupied with the Soma cube for five minutes during the waiting time - one minute longer than the day before. On the following day, this time dropped to only three minutes, because there was no reward. This represented the worst daily

result. Deci concluded from this: *"When money is used as an external reward for some activity, the subjects lose intrinsic interest."* (Deci, 1971)

More generally speaking, the absence of a reward also leads to a decrease in motivation and thus ultimately to the cessation of the activity or interest in the matter Kohn (1999). Harlow et al. (1950) already suspected that intrinsic motivation could be used to facilitate learning. Accordingly, games are the method of choice. These are played voluntarily and for the fun of it. Learning does not always happen on this basis. It can be motivated by personal interest *(intrinsic)* but also by external goals *(extrinsic)* such as grades or desired profession. The task of the Serious Game would therefore be to help the player to achieve extrinsic goals in a pleasant way through the intrinsically motivated action of playing. If the game is only played in order to gain a certain knowledge, which is needed e.g. to pass an exam, then even playing is extrinsically motivated (Dörner et al., 2016).

Octalysis Framework: In his Gamification design framework Octalysis (see Figure 2.4), Yu-kai Chou (2015) defines 8 different facts, so-called core drives, which are decisive for the motivation of people to complete a task:

1. *Epic Meaning and Calling:* Motivation can be drawn from the fact when people feel chosen to perform a certain activity. This is done on their own initiative and is not aimed at external rewards. Social engagement or commitment to the environment are examples of this. In terms of games, this would be an unpaid commitment to the community.

2. *Development and Accomplishment:* Solving a task and observing one's own progress is motivating. A reward for the achievement can additionally strengthen this effect. The reward of points for achievements is a very popular game element.

3. *Empowerment of Creativity and Feedback:* The opportunity to be creative and develop new things motivates people. Positive feedback reinforces this effect. This can be seen in particular in arts activities.

4. *Ownership and Possession:* Humans care about their possessions. When elements of a game such as the avatar, certain objects or premises are perceived as the player's property, the motivation to improve or embellish these elements arises.

5. *Social Influence and Relatedness:* Humans are social and political beings (ζῷον πολιτικόν[1]). Thus, they like to form communities or maintain social contacts. This is also connected with the striving to find attention within society. In games, especially role-play games, there are clans or guilds in which the players organize themselves. Motivation can basically come from playing with other people, but can also arise from social pressure. Either one would like to get achievements that other players already have or one would like to differentiate oneself from the

[1] Aristot. Pol. 1253a1-11

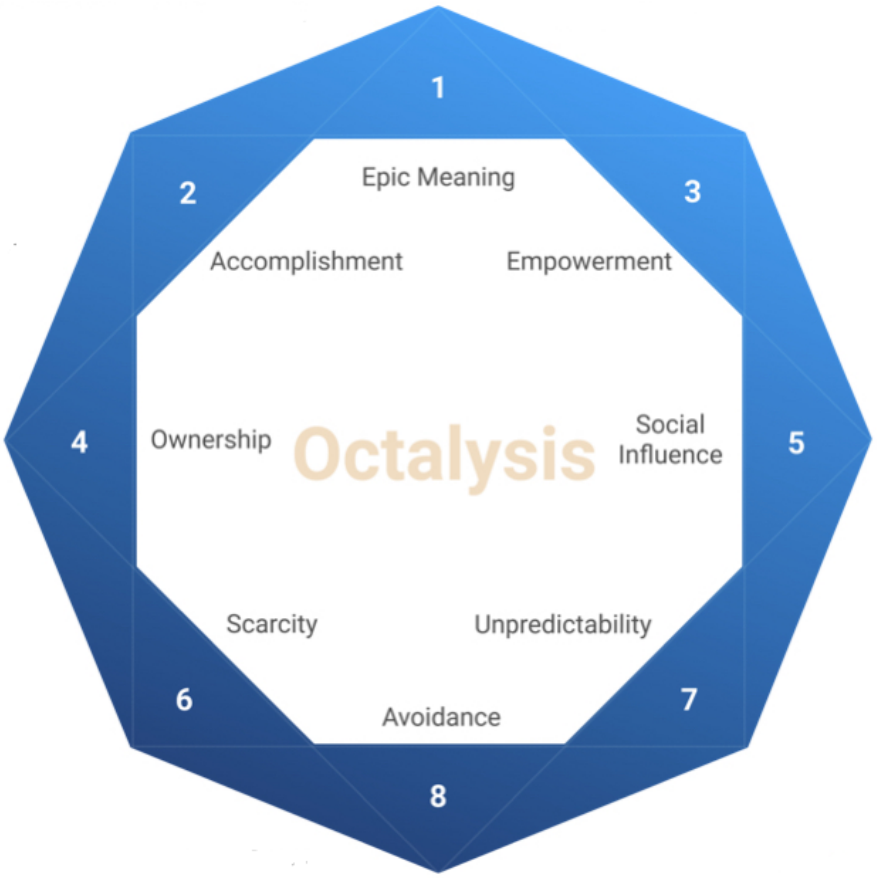


Figure 2.4.: Octalysis Framework according to Yu-kai Chou (Chou, 2015)

community through special items or titles, which can only be obtained through increased effort.

6. *Scarcity and Impatience:* Scarcity can also be a motivating factor. Games are often not released in all countries at the same time, so the waiting time affects the motivation to play the game. It is also possible that special events or quests in the game can only be executed at certain times, so the player has to wait impatiently.

7. *Unpredictability and Curiosity:* People's curiosity drives them. Exploring new areas or finding out the end of a story are strong motivators. However, the unpredictable is not only positive. Lotteries and other elements where chance decides often create a certain addiction.

8. *Loss and Avoidance:* The fear of losing something that you have tediously built up can be just as motivating. This can also be called compulsion. An activity such as constantly checking to see if you are being attacked by your opponents, or completing certain tasks concerning the clan for fear of having to leave it otherwise, are among them.

If none of these drives are present, there is no motivation. Additionally these core-drives can now be assigned to intrinsic and also extrinsic motivation:

Accomplishment (2), Ownership (4) and Impatience (6) belong to the extrinsic motivation. They symbolize the (impatient) pursuit of reward, acknowledgement or possession. Social Influence (5) is sometimes combined with peer pressure. In this case, it can also be classified as external drive.

Empowerment (3), Relatedness (5) and Curiosity (7) are belonging to the intrinsic motivation. The players are performing the activities because they really want to do that. So, no further reward is needed.

White Hat and Black Hat Motivation: Furthermore, the drives mentioned can be divided into positive motivators *(white hat)* and negative motivators *(black hat)*:

- **White Hat:** Motivation arises from the desire to achieve something. This can be self-chosen goals, but also rewards that are specifically linked to a task. This is associated with positive feelings. This concerns the drives Epic Meaning (1), Accomplishment (2) and Empowerment (3).
- **Black Hat:** With the drives Scarcity (6), Unpredictability (7) and Loss (8) the players are made to perform an activity that they might not have done. This procedure is associated with rather negative feelings. Waiting time could be disturbing. Likewise, if the unpredictable coincidence does not supply a desired result. Fear of losing something can trigger a kind of compulsion.

  Although these drives are connected with negative feelings, this does not mean that they should not be used. These are strong motivators and can still have a positive effect, if they are e.g.used to promote the player's health.

2.2. Player Experience

Figure 2.5.: Player Experience influences Intrinsic Motivation and Learning

"When people are intrinsically motivated to learn, they not only learn more, they also have a more positive experience" (Chan & Ahern, 1999)

This is especially true for games, as they cause the so-called player experience, which evokes enthusiasm and lets the player dive into other worlds. The key factor for Serious

Player Experience - Generic Model	
Immersion and Presence	ARCS Model
Self-Determination Theory (SDT)	Flow

Table 2.1.: Player Experience - Generic Model according to Wiemeyer et al. (2016)

Games is not only to create a positive feeling, but also to use and to increase the intrinsic motivation for knowledge acquisition and transfer (Bizzocchi & Paras, 2005). The player experience itself is a complicated and multi-layered concept, which is tried to be described by different psychological models.
Wiemeyer, Nacke, Moser, et al. (2016) divide this phenomenon into a generic and a domain-specific model. The generic model (see Table 2.1) contains the elements *Presence and Immersion*, the *ARCS Model*, the *Self-Determination-Theory* and the *Flow* concept. These elements will be examined in more detail in the following:

2.2.1. Immersion and Presence

These two concepts belong together. Immersion literally describes the submersion of the player into the game world. If this effect is reinforced by corresponding game elements, the virtual world increasingly displaces reality. Presence, finally, describes the state in which the player identifies with the game character and also perceives the virtual world more and more as real. Especially in the field of Virtual Reality (VR), a high degree of immersion can be observed, since the real movements of the player are directly transferred to the virtual world (Mütterlein, 2018).

If we take a closer look at the topic of immersion, it is possible to subdivide this into further subgroups according to Ermi and Mäyrä (2005):

- *Sensory Immersion:* Audiovisual aspects are responsible for immersion. The more appealing graphics and audio are designed, the more likely immersion is created. This effect could be intensified by addressing tactile, gustatory or olfactory senses.
- *Imaginative Immersion:* The story and the world in which the story takes place are particularly important. The immersion depends on the extent to which the player can identify with the characters presented and the extent to which he can be absorbed into the story world through the use of his imagination.
- *Challenged-based Immersion:* In this case the state of immersion is based on the user's ability to master challenges and therefore this subgroup of immersion is very similar to the concept of flow (see section 2.2.4)

2.2.2. ARCS Model

Keller (2009) introduced the ARCS model. This model consists of four conditions which are responsible for getting and staying motivated:

- ***A**ttention:* Creating curiosity and interest of the player.
- ***R**elevance:* All actions must be understandable and comprehensible for the player. This prevents frustration and demotivation.
- ***C**onfidence or the "expectancy of success":* The player has to be convinced that the tasks can be solved with the appropriate effort. If the success depends mainly on chance, this can lead to frustration.
- ***S**atisfaction:* Rewards for correctly executed actions or correct application of the newly learned skills lead to satisfaction for the player.

2.2.3. Self-Determination Theory (SDT)

Figure 2.6.: Motivational Continuum of the Self-Determination Theory (SDT) according to Ryan & Deci (2000)

According to this theory of Ryan & Deci (2000), extrinsic and intrinsic motivation form the extrema of a continuum classified by self-determination (see Figure 2.6). To achieve intrinsic motivation and thus complete self-determination, three factors called *"human's three basic needs"* must be fulfilled:

- *Autonomy* (self-reliance, independence): The more freedom the player has to make his own decisions, the higher is the resulting intrinsic motivation. Examples would be the self-determination of the order in which quests are accepted and completed.
- *Competence* (self-efficacy): The player should have the feeling of being able to master the set challenges well. Positive feedback additionally increases intrinsic motivation.
- *Relatedness:* Social relationships and the feeling of being accepted by the group or fellow players (belongingness) are essential.

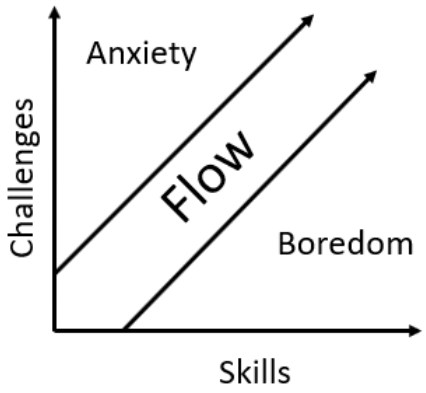


Figure 2.7.: Flow State Model, adapted from Csikszentmihalyi (2014)

2.2.4. The Concept of Flow

The concept of flow uses similar to the SDT the element of competence and its relation to a positive player experience or enjoyment. The state of flow can only be achieved if the player feels able to solve the tasks set without being under- or overchallenged. Flow describes a state in which a person concentrates and focuses so much on his activity that he loses sight of everything around him. One can also say that he is in the zone. It is a state of complete immersion, which can cause creative power, enthusiasm and enjoyment. The broadly accepted *"Flow State Model"* was introduced by Csikszentmihalyi (1975). His research showed that enjoyment is experienced in a similar way in different activities, independent of social status, gender or age (Sweetser & Wyeth, 2005).

The state of flow can be characterised as follows according to Nakamura and Csikszentmihalyi (2014):

- Focused attention on the activity
- Merging of action and awareness
- Loss of reflective self-consciousness
- Sense of personal control over the activity or situation
- Distortion of temporal experience
- Experience of the activity as intrinsically rewarding

How can the state of flow be achieved? As shown in Figure 2.7, the balance between challenge and skill is crucial. The optimal experience can occur in the so-called flow channel, in which challenge and skills more or less balance each other. On the other hand, if the challenge is too much for the existing skills, this leads to excessive demands and anxiety. In the opposite case, underchallenge and boredom arise. Both effects lead

to a decrease in intrinsic motivation. (Csikszentmihalyi, 1975, 2014; Csikszentmihalyi & Csikszentmihalyi, 1988)

Csikszentmihalyi summarizes the conditions for flow as follows (Csikszentmihalyi, 2014):

- *"Perceived challenges, or opportunities for action, that stretch (neither overmatching nor underutilizing) existing skills; a sense that one is engaging challenges at a level appropriate to one's capacities"*
- *"Clear proximal goals and immediate feedback"*

The flow model was extended by further research. As a result, not all parts of the flow channel will actually reach the state of flow. This occurs when challenge and skill are at a very low level. In this case one speaks of apathy. How much skill and challenge is necessary varies from person to person. (Csikszentmihalyi, 1997; Massimini & Carli, 1988).

While the flow model of Csikszentmihalyi is generally applicable to any activity, Sweetser et al. (2005) applied it specifically to games. The concept of the so-called GameFlow thereby tries to investigate the phenomenon of the enjoyment of playing. The GameFlow consists of the following eight elements:

1. **Concentration** - *"Games should require concentration and the player should be able to concentrate on the game"*
2. **Challenge** - *"Games should be sufficiently challenging and match the player's skill level"*
3. **Skills** - *"Games must support player skill development and mastery"*
4. **Control** - *"Players should feel a sense of control over their actions in the game"*
5. **Clear Goals** - *"Games should provide the player with clear goals at appropriate times"*
6. **Feedback** - *"Players must receive appropriate feedback at appropriate times"*
7. **Immersion** - *"Players should experience deep but effortless involvement in the game"*
8. **Social Interaction** - *"Games should support and create opportunities for social interaction"*

In many different studies Sweetser et al. (Sweetser, Johnson, & Wyeth, 2012; Sweetser et al., 2017; Sweetser & Wyeth, 2005) developed criteria to evaluate games based on the individual elements of GameFlow. This enabled them to make statements about the success and failure of games.

2.3. Guidelines for Serious Games Design

All of the elements of the player experience mentioned above, especially the flow model, are fundamental to the enthusiasm and intrinsic motivation associated with playing. As already mentioned, it is precisely this kind of motivation that is decisive for learning through playing. What should be adopted from the many theoretical models for the development of a Serious Game and what should be followed? Probably the most important thing is that a Serious Game must fulfill all the requirements of a game (Wong et al., 2007) in order for the magic, as Bowman (1982) calls it, to arise.

Many digital Serious Games fail because great importance is attached to the teaching and preparation of the learning content, but the playful elements such as graphics, story, controls, etc. are neglected and therefore can not compete at all with other well-known and successful games (Kirriemuir & Mcfarlane, 2004). Squire & Jenkins make the following harsh judgment: *"most existing edutainment products combine the entertainment value of a bad lecture with the educational value of a bad game"* (Squire & Jenkins, 2003, p. 8). Serious Games of this kind used in schools often do not have the desired effect, the so-called *"motivational pull"* (Wouters, Van der Spek, & Van Oostendorp, 2009). According to Huizinga (2014), playing *"is in fact freedom"*. When pupils have to play the game, the game looses its power so to say. The decrease of motivation to play, because it is not purely voluntary any more, dilutes probably the impact of Serious Games on motivation and learning effects. (Wouters, Van Nimwegen, Van Oostendorp, & Van Der Spek, 2013).

Developing digital Serious Games is extremely complex, if they should meet all requirements. Ideally, a team for the development of Serious Games is interdisciplinary. Experts in the development of digital games, such as programmers and designers, must work together with experts in the learning content to turn the player experience into a learning experience. This only works in an iterative game development process. After the joint planning and subsequent implementation, a joint evaluation with test persons takes place. The results and the feedback are transferred to the next development cycle. The Serious Game development framework by Abeele et al. (2011) summarizes this as follows:

- Iterative Development
- Interdisciplinary Teamwork
- Integration of Play and Learning
- Player-Centered Design

Player-Centered Design is understood to particularly consider the demands and needs of the player. We would like to refer here once again to the ARCS model (Keller, 2009). In order to achieve attention (A), the game must satisfy the needs (S) of one or preferably several types of players. According to Bartle (1996) there are four different types:

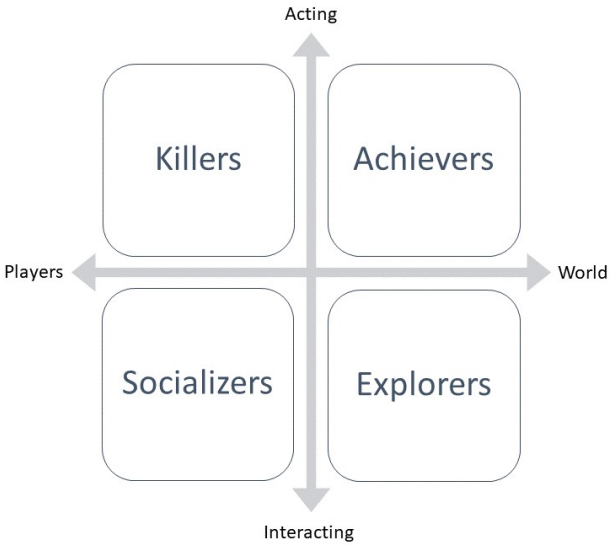


Figure 2.8.: Playertypes according to Bartle (1996)

- **Achievers** want to achieve as much as possible in the game (points, rankings, items).
- **Explorers** try to discover as much as possible in the game (game world, quests)
- **Socializers** aim for social interaction with other players.
- **Killers** strive for competition and also conflict with other players.

The choice of the game genre is already essential to get the attention of the respective player type. Furthermore, it also plays a decisive role in relatedness. The learning content should be chosen to match the game content, so that both are interwoven in a meaningful and comprehensible way.

Defintion of *meaningful play* (Salen, Tekinbaş, & Zimmerman, 2004): *"Meaningful play in a game emerges from the relationship between player action and system outcome; it is the process by which a player takes action within the designed system of a game and the system responds to the action. The meaning of an action in a game resides in the relationship between action and outcome"*.

What should be considered when designing the game and learning elements? Flow seems to be a key element, since the fulfillment of the conditions for flow also positively

influences some other elements of the player experience and thus also the intrinsic motivation:

Flow and Immersion: As mentioned in section 2.2.1, flow and immersion have something in common. Challenge-based immersion can also be triggered by a correctly defined challenge. In order to show the connections between flow and immersion, Kannegieser, Atorf, and Meier (2019) chose the definition of engagement-based or challenge-based immersion according to Cairns (2006) and compared it with the conditions for flow according to Csikszentmihalyi (2014). Figure 2.9 illustrates the result. According to Cairns (2006), this type of immersion is divided into three levels: engagement, engrossment and total immersion. If we look in particular at total immersion, we find that there are similarities to flow both in the precondition and in the direct consequence. Both in the state of flow and total immersion, the player's reference to reality disappears. In the case of immersion, the real world is replaced for a certain time by the game world in which the player now feels present. In the state of flow, the person is so busy with an activity respectively playing, that he loses all sense of time and concentrates only on the game. In both cases, it is important that the challenge is not too demanding and is adapted to the player's abilities, so that the player has the feeling of being in control of what is happening at all times.

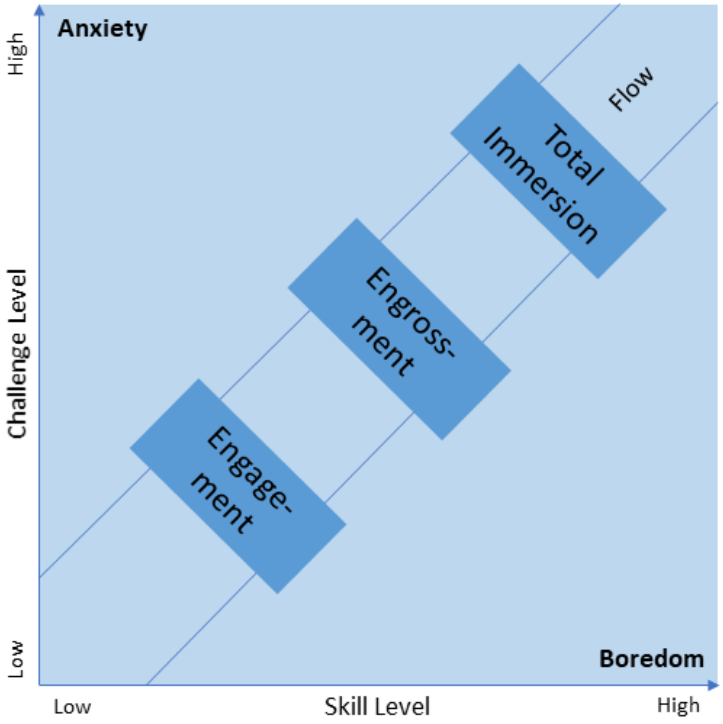


Figure 2.9.: Combined Model of Flow and Immersion according to Kannegieser et al. (2019)

Flow and Confidence are also closely connected. Confidence is an important element of the ARCS model by Keller (2009). If one considers the balance between challenge and skill of the player at any given time, the player is also convinced that he can meet the challenge with manageable effort.

Flow in Serious Games We believe that the concept of flow is not only an important component of the player experience, but a key element for the success of a Serious Game. Especially this balance from the flow model is doubly valid in a Serious Game.

A Serious Game is known to be characterized by the interweaving of the gaming layer with at least one "serious" layer for further purposes. It is therefore only logical to apply the rules of flow consistently to both layers. We have therefore developed a scheme for Serious Games that are designed to transfer knowledge to the player (see Figure 2.11). First, gaming elements (G) and learning elements (L) are considered separately. Both times the rules for flow have to be fulfilled individually. For the gaming elements this means that game controls and interaction possibilities have to be explained and introduced before they are executed correctly, for example in a faster sequence or under time pressure. Challenge and gaming skills have to be balanced. This applies analogously to the learning elements. Here, the new knowledge must first be playfully tested in simple contexts. Since repetition is also part of learning, it is necessary to offer not only different levels of difficulty, but also different ways of testing knowledge, for example in the form of different puzzles. Figure 2.11 also shows a combined flow diagram. The axes symbolize the respective relationship between challenge and skill with respect to the learning elements (L) and the gaming elements (G). The previous flow channel is now marked here as a circle around the origin. The area of this circle is the *"sweetspot"* (Wong et al., 2007), i.e. the area in which the conditions for flow are fulfilled in both the learning and the gaming layer.

This scheme shows the multi-layered meaning of flow for Serious Games. If this is considered when creating a Serious Game, an important step has been taken. However, there are other problems to be solved:

"A game that maintains a consistent level of information presentation, demonstration, and practice without taking into consideration the knowledge and skill level of the learner will be less successful. As learners acquire the knowledge and skills, which will occur at different rates for each learner, the game should recognize this acquisition and adjust accordingly" (Prensky, 2003)

For one thing, each player is different in terms of their abilities in the game as well as in the learning domain. For another thing, flow is not a static state (Chen, 2007) - see Figure 2.10.

Flow is usually checked at the end of the game in the form of a questionnaire. However, this only allows a statement to be made about the state of flow at the end of the game. Therefore, mechanisms are needed which enable all players to reach the state of flow despite different previous knowledge or playing experience. This can be

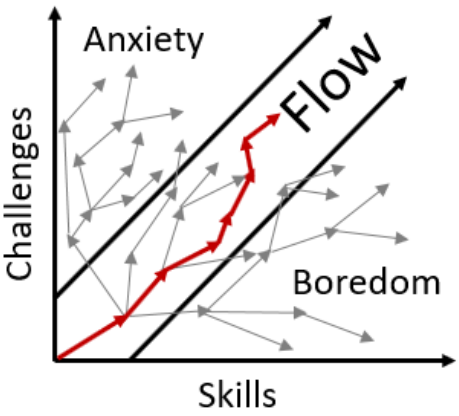


Figure 2.10.: Adaptive Flow in Games (Herber, 2019), adapted from Chen (2007)

done by a step-like help and hint system. If a task is not solved or the player does not perform any or no meaningful action for a longer time, hints can be displayed. These should offer step-by-step help to solve the task. In this way, both overchallenge and underchallenge is prevented. Both would be reasons for the player either not to reach the state of flow or to abort the game if these negative effects exist for a longer period of time. The ideal solution, which should guarantee that the player can reach the state of flow at any time, is an automatic adjustment of the individual difficulties of the learning and the game level. However, this presupposes that subdivisions of the game, e.g. levels, are chosen as the basis for evaluation in order to make the further course of the game flexible and tailored to the player.

The procedure of automatic difficulty adjustment has already been tested on the example of an exergame. The so-called *"Dual Flow"* was researched by Sinclair (2011). The players played while training on the exercise bike. The game was influenced by data on the speed and heart rate of the player. This way, over- or underchallenge was avoided and the player did not stop the game and consequently the training prematurely.

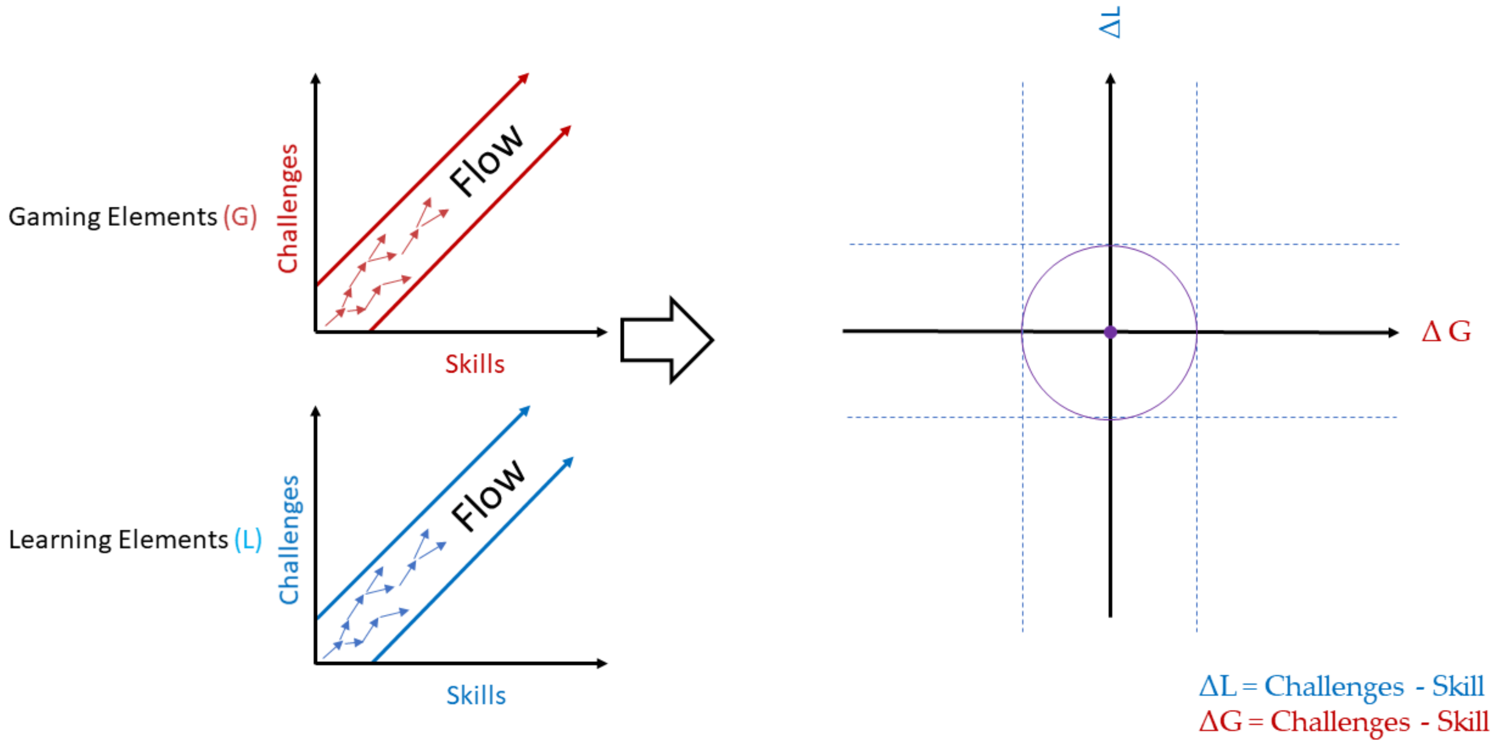


Figure 2.11.: Combined Flow (Plecher&Herber)

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3. Game Elements

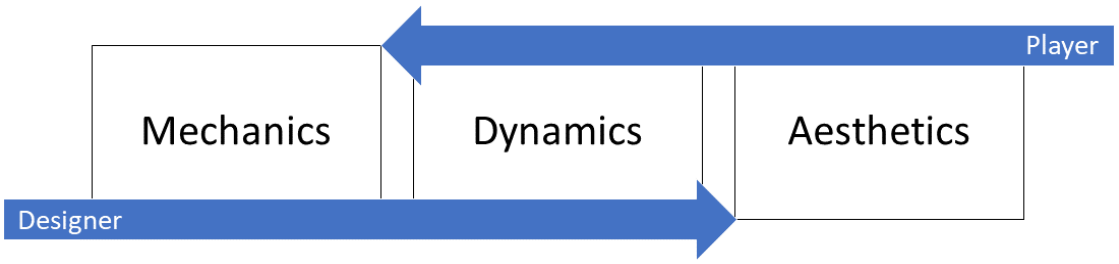


Figure 3.1.: MDA Framework according to Hunicke et al. (2004)

In the previous chapters we described the psychological factors and effects that are essential for an ideal Serious Game. In the following, we will look at the actual game mechanics that make these effects possible. When considering the individual components of a game, it is important to keep in mind that they can be viewed from two different perspectives. On the one hand there is the view of the designers, who create the game and on the other hand the players, who play the game. For the designers, there are the individual components of the game, which were put together with the goal of satisfying the player. The player sees the result as a whole and evaluates it in the context of all the components working together. The designer's intention and the resulting effect can diverge, because on the one hand interactions can occur, and on the other hand the players perceive and evaluate this differently.

Hunicke's MDA framework (see Figure 3.1) uses an abstract model to help analyze the different perspectives of designers and players (Hunicke et al., 2004). The model consists of the following three layers:

- *Mechanics* refers to the technical components of the game.
- *Dynamics* refers to the adjustment of the mechanics based on the player's input.
- *Aesthetics* refers to the feelings the game evokes in the player.

The designer only has influence on the mechanics. The selection and composition of these influences the dynamics, which finally produce the corresponding aesthetics. The player, on the other hand, has no influence on the mechanics, but experiences the resulting aesthetics.

3.1. Aesthetics

Games are supposed to be fun, but fun is manifold and difficult to quantify. Every player experiences the game differently. For a better analysis of the parameter "fun", aesthetics are introduced. Aesthetics are the psychosocial consequences (Abeele, Spiel, Nacke, Johnson, & Gerling, 2020) of gaming and they basically describe everything that the player can perceive and feel. In the model, examples of emotions that the player can have during the game are summarized (see Table 3.1).

Aesthetics	**Explanation**	**Game Mechanics**
Sensation	"game as sense-pleasure"	AR, graphics, sounds
Fantasy	"game as make-believe"	storyworlds
Narrative	"game as drama"	story, characters
Challenge	"game as obstacle course"	quests, fights, multiplayer (competitive)
Fellowship	"game as a social framework"	multiplayer (cooperative)
Discovery	"game as uncharted territory"	(open) game world
Expression	"game as self-discovery"	creative potential
Submission	"game as pastime"	deflection

Table 3.1.: Aesthetics according to the MDA Framework (Hunicke et al., 2004) with examples of corresponding Game Mechanics

All these different emotions can be motivators for a player to play the game. It is essential for the designer to choose the right Game Mechanics the player can dynamically interact with to evoke these emotions.

3.2. Dynamics

Aesthetics are created by Dynamics, which are the functional consequences of Game Mechanics (Abeele et al., 2020). The latter specify certain rules, on the basis of which the player adjusts his game behavior. This process is called Dynamics. For example, if the game mechanics only allow a certain amount of time to complete a quest, this results in time pressure (Dynamics). The emotion (Aesthetics) that arises is challenge.

3.3. Game Mechanics

Game Mechanics are the components of the game that the designers can select and combine. Their intention is to trigger certain emotions in the player. There is a variety of different game mechanics and their selection ultimately determines the functioning of a game.

In the following, we focus on Game Mechanics that were important for the developed Serious Games:

3.3.1. Storytelling

This Game Mechanic is strongly related to the aestethic narrative. The player should be interested in the story. The motivation to continue playing the game can be based on finding out the further course and finally the end of the story. This effect can be enhanced if the player can identify with the avatar or other characters in the game.

3.3.2. Multiplayer

Playing together with other people can be a motivator. It is strongly related to the aesthetic fellowship and to the core drive social influence from the Octalysis framework. Playing with multiple players can happen in two different modes: In competitive mode, players are in competition against each other. On the other hand, in cooperative mode, players act together. The effects of collaboration and competition were investigated by Siu et al. (2014) using a game with a purpose focusing on engagement and accuracy. They found that the data in collaborative and competitive mode hardly differed with respect to accuracy. With regard to engagement, however, the competitive mode achieved the higher values. An interesting finding was that the use of a game mode that allowed both competitive and collaborative options led to a deterioration of the scores, as the players were overwhelmed by the increased number of possible strategies.

3.3.3. Augmented Reality

Since Augmented Reality (AR) is used in two of the games introduced in this work, we would like to present this in detail here as well. AR is the three-dimensional embedding of virtual information into reality, which can be perceived by the human senses. In the following we would like to focus on the augmentation of the visible world. With the help of various types of displays such as smartphones, tablets or head-mounted displays, virtual objects are brought into the user's field of view. Azuma (1997) provided the best known definition:

1. Combination of real and virtual worlds
2. Real-time interaction
3. Registration in 3D

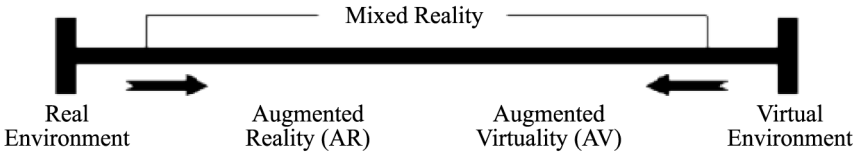


Figure 3.2.: Reality-Virtuality Continuum (Milgram & Kishino, 1994)

The exact distinction from Virtual Reality (VR) is illustrated by reality-virtuality-continuum from Milgram and Kishino (1994) (see Figure 3.2). The extrema are formed by depending on the degree of virtual information: Pure reality as perceived by the human eye and complete VR, which no longer has any real references. In between, the so-called Mixed Reality (MR), there are the hybrid forms, AR and Augmented Virtuality (AV). AR describes the state in which virtual objects are added to reality, whereby the real part still predominates. With regard to the AV, it is exactly the opposite situation. In our examples, tablets serve as displays and printed beer mats as markers. These can be recognized by the camera of the device and serve as reference points to position the virtual objects in real 3D space. This is called environment mounting (Tönnis, Plecher, & Klinker, 2013).

Effects of AR Khan, Johnston, and Ophoff (2019) examined the influence of AR on learning motivation. In addition, they considered this in relation to the ARCS model (Keller, 2009). In particular, an increase in the values for Attention was found. In addition to this, the following studies examine the effects of AR on motivation and flow:

Di Serio, Ibáñez, and Kloos (2013) showed that AR has a positive effect on the motivation of middle school students. In a two-part study, participants were presented with Italian Renaissance art in two different ways. First in the form of a classical lecture and later using an AR app. The selected art works and the corresponding information were different in the lecture and the app. Afterwards, a questionnaire based on the Instructional Materials Motivation Survey (IMMS) (Keller, 2009) of 55 participating students (29 female, 26 male) was evaluated. The classical lecture achieved a motivation mean score of M = 3.29 and therefore significantly lower than the AR app with M = 3.62.

Ibáñez, Di Serio, Villarán, and Kloos (2014) investigated the influence of the use of AR on flow. In the study basic knowledge about electromagnetism was provided web-based and AR-based. 60 students (15 female, 45 male) aged 17-19 years participated in the study. The knowledge gain was determined by a pre/post questionnaire. The flow was measured by the Flow State Scale (Jackson & Marsh, 1996). The experimental group (n=28) using the AR based application showed not only a higher knowledge gain but also a higher degree of flow.

In all studies on this topic it should be noted that the results are also influenced by external effects. Technical problems or the overstraining of the inexperienced user lead to negative feelings and a break with immersion and flow. In this way the results can be negatively influenced. On the other hand, the so-called novelty effect leads to a unique and very positive experience, which cannot be repeated or transferred to other AR applications.

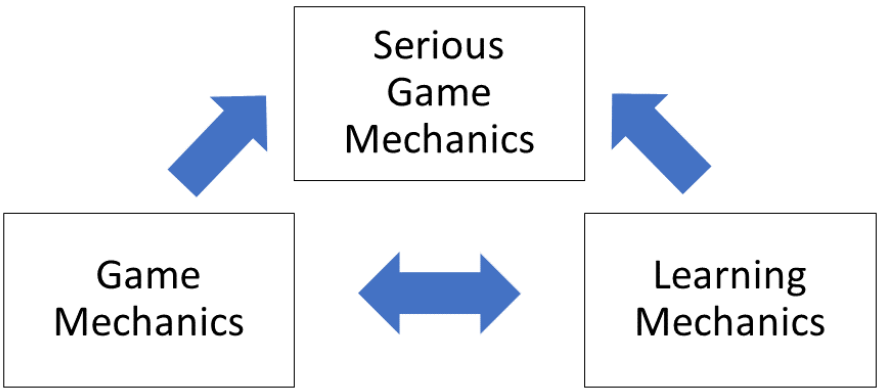


Figure 3.3.: Serious Game Mechanics according to Arnab et al. (2015)

3.4. Serious Game Mechanics

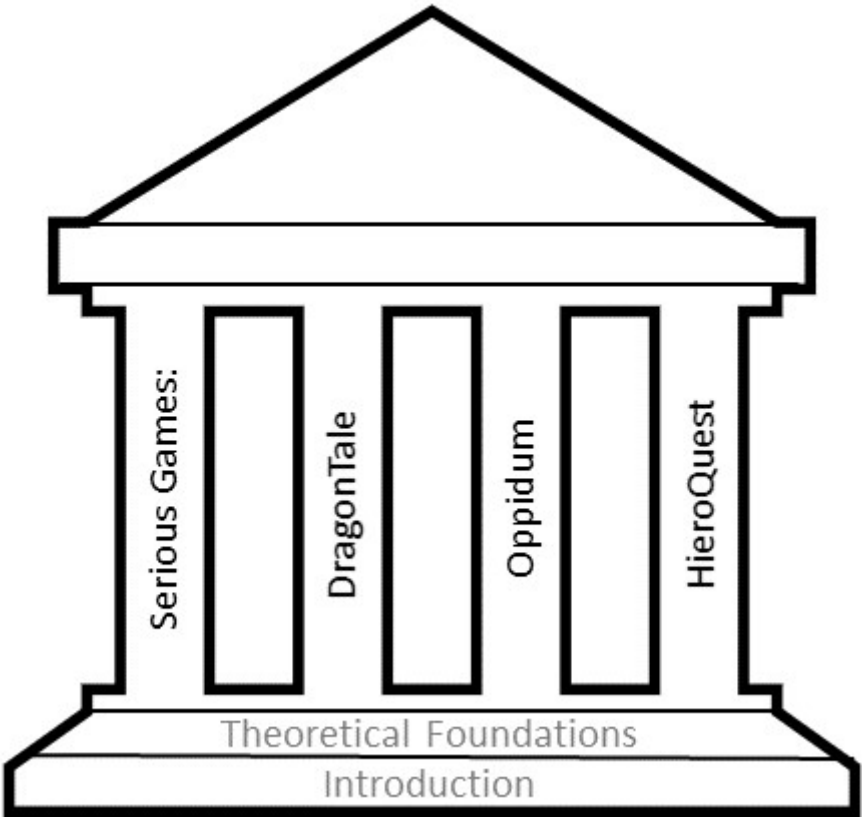
Knowledge transfer can only happen by embedding the learning process (see section 2.1.4) into the game. So, it is necessary to combine the aforementioned Game Mechanics (GM) with the Learning Mechanics (LM). Arnab et al. (2015) developed the LM-GM model for this purpose. Learning mechanics include, among many others: Repetition, Feedback, Exploration, Identification.

On the one hand, Game Mechanics have the task to evoke certain emotions (Aesthetics) in order to provide the player with the desired player experience; on the other hand, Game Mechanics are important to support or enable the learning process.

For Serious Games it is essential to choose these Mechanics in a way that they create the necessary fun, but also convey the serious content in combination with certain learning mechanics in the most appropriate way to generate a learning experience.

Part II.

Serious Games
(*Columns*)



4. Effects of Serious Games

In this chapter the different effects are described that can be achieved by Serious Games or for which higher goals they are used. Main targets are learning and knowledge transfer, but the variety of effects certainly go beyond that. Especially in the medical field Serious Games are used to change the player's behavior in real life. This can be done by dedicated information, which is passed on to the player, so that the advantages and disadvantages of certain behavior patterns are recognized and adjusted accordingly.

4.1. Behavioral Change

Already in the 90s, some games for the Super Nintendo Entertainment System (SNES) were created and designed especially for children with chronic diseases:

Bronkie the Bronchiasaurus (1995) addresses children with asthma. The game is about a dinosaur called Bronkie, who, like many of his conspecifics, also suffers from this disease after a meteorite impact and the resulting dust cloud. They playfully explain not only the reasons for asthma attacks, such as smoke or dust, but also the correct use of the asthma inhaler in case of an attack. (Knauf, 1996)

Packy and Marlon (1995) is the most famous game in the SNES series for chronically ill children. It is about two elephants (Packy and Marlon), which suffer from diabetes. The player has to support these two in their fight against rats. During the game the elephants collect food and insulin. It is important to balance the blood sugar level by eating or taking insulin at the right time. This requires the player to attentively monitor the blood sugar level. In 1997, a study was conducted by Stanford University to investigate the effectiveness of this game (Brown et al., 1997). 59 children with diabetes between the ages of 8 and 16 took part in this study over a period of 6 months. 31 children played 'Packy and Marlon' and the control group of 29 children played another game on the SNES that had no medical content. A survey showed no significant differences in knowledge about the disease. However, the patients in the experimental group paid more attention to their blood glucose levels during the course of the study. The average number of urgent visits to the doctor per child due to diabetes decreased in this group from 0.57 in the first three months to 0.13 in the last three months. In the control group this effect could not be observed, the value even increased slightly. Consequently, 'Packy and Marlon' could successfully influence and change the behavior of the players.

Figure 4.1.: 'Fit, Food, Fun' (Schäfer et al., 2017)

Another important topic that affects all parts of society is nutrition. Obesity is a major health risk, so various games have been developed with the aim of changing the dietary habits of players.

One example is our game 'Fit, Food, Fun' (Schäfer et al., 2017), which was supported by the enable-cluster[1] and funded by a grant of the German Ministry for Education and Research (BMBF) FK 01EA1409A. It was developed especially for teenagers and young adults. The game is played on the smartphone. The player goes on a virtual journey through Europe (see Figure 4.1) and has to complete different mini-games in connection with nutrition and food decisions. For certain sporting activities, such as cycling, running or swimming, a rucksack with provisions must be packed. Here you can choose from different standardized or country-specific dishes, food and beverages. At the end of each mini-game, the player's choices are evaluated. It is analyzed whether too many or too few calories were packed, as well as whether sufficient beverages were taken. In addition, recommendations are made how to replace unhealthy food by healthier choices.

The games mentioned so far have provided information and clues, based on the hope that the players will use them in real life and change their behavior. Due to the progress of technical development, it is now possible to measure and track real life actions. The collected data can be used to influence the game events. The game 'Pokémon Go' became very famous because it more or less turned the whole world into a playing surface. The Pokémons were placed at certain positions in the real world and the players have to physically move there to collect them. Many players were thus motivated to walk more

[1] http://enable-cluster.de (last access 2020/09/15)

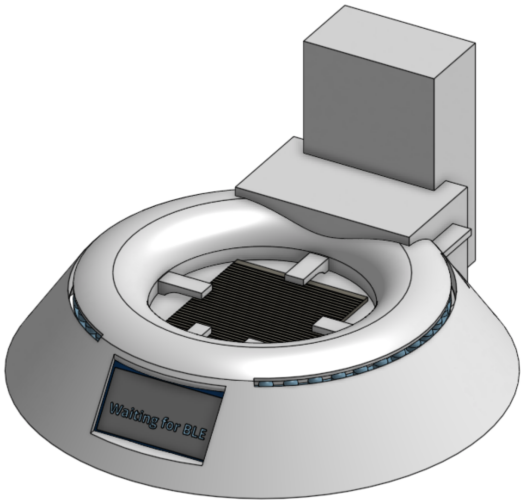


Figure 4.2.: Drinking Gadget for the elderly (Plecher, Eichhorn, Lurz, et al., 2019)

and covered some more kilometers than usual. Althoff et al. proved this effect based on the data of 32,000 Microsoft Band users. Over a period of 30 days, active users increased their average daily distance by 1473 steps (Althoff, White, & Horvitz, 2016).

Serious Games for health are using a similar approach. For example, 'SpaPlay' is a classic construction game with the goal to manage a spa resort. In order to progress in the game, points must be collected. This is possible by documenting the users' daily meals in the game. Healthy meals and drinks provide points. It is possible to earn points by walking as many kilometers as possible or by using the stairs instead of the elevator. This movement data can be collected by the smartphone and need not to be entered additionally. 47 women participated in a study over a time period of 90 days. Two different effects occurred. On average the Body Mass Index (BMI) of the participants decreased during the study from 27 to 26.1. Additionally the knowledge about healthy nutrition, measured by a pre- and post-test, increased. (Shiyko, Hallinan, Seif El-Nasr, Subramanian, & Castaneda-Sceppa, 2016)

Serious Games to improve or maintain health are also available for the elderly. In this age group, physical and cognitive problems become apparent in particular when the fluid intake per day is not sufficient. There are many reasons for dehydration, e.g. the sensation of thirst decreases with age (Volkert, Kreuel, & Stehle, 2005) or the elderly simply forget to drink. Within the enable-cluster[2] and funded by a grant of the German Ministry for Education and Research (BMBF) FK 01EA1409H, we made it our task to find solutions and support methods for this problem.

Since fluid intake is not as easy to measure with the Smartphone as counting steps, a gadget has to be developed first (see Figure 4.2). This gadget is made by a 3D printer and has a weight sensor which can determine the amount of liquid that was drunk.

[2]http://enable-cluster.de (last access 2020/09/15)

The integrated Arduino controller supplies the devices connected via Bluetooth like smartphones or tablets with the measured data. Information can also be shown on the built-in display. Serious Games can now simply pause and remind the elderly to drink or integrate the amount drunk directly into the game. Figure 4.3 shows a small selection of the games developed in this project. These are especially designed for the elderly. The Balloon Game is intended to promote an introduction to the use of the touch screen. The goal is to make the balloons explode by clicking on them. The pairwise matching game and the crossword game are known to seniors in their analogous form and are intended to train cognitive abilities. These games are adjustable in their difficulty and can therefore be played even with a mild to moderate Alzheimer's disease. All games remind the player to drink after a certain time or after reaching a certain score. Only when the gadget detects a decrease in the amount of liquid in the glass or cup, the game can be continued. A small study with five residents of a nursery home was conducted. While playing the games the participants consumed around 400 milliliters per hour and did on average 11 drinking actions. (Eichhorn et al., 2018, 2019, 2020; Plecher, Eichhorn, Lurz, et al., 2019)

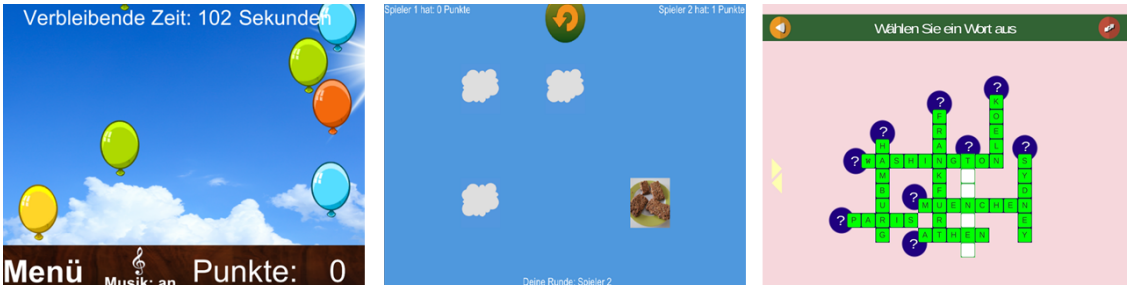


Figure 4.3.: Serious Games for the elderly: Balloon Game (left), Pairwise matching Game (middle), Crossword Game (right) (Eichhorn et al., 2019)

4.2. Knowledge Transfer

Presumably the best known effect of Serious Games is to transfer knowledge to the player. Basically knowledge is divided into four different areas (Bransford, Brown, Cocking, et al., 2000):

1. Declarative knowledge - "Knowing-that", knowledge of facts
2. Procedural knowledge - "Knowing-how", knowing how to perform a task e.g. Assembly Task (Palmas, Labode, Plecher, & Klinker, 2019)
3. Strategic knowledge (conditional knowledge) - strategies to gain knowledge
4. Metacognitive knowledge - combination of the named declarative, procedural and strategic knowledge

The *declarative knowledge* describes the factual knowledge. Therefore, it is also called 'knowing-what'. Examples would be vocabulary or dates of historical events. *Procedural knowledge* on the other hand deals with the knowledge of processes and sequences. Thus it is also called 'knowing-how'. Often declarative knowledge is needed to understand the processes. Examples for this are learned and subsequently automatically executed movement processes such as skating or steps executed in a fixed sequence when changing a car tire. *Strategic* or *conditional knowledge* is the awareness of strategies to gain and to remember information. *Metacognitive knowledge* describes the assessment and reflection of one's own knowledge. It is also called 'knowing about knowing'. This is the own evaluation of which information is easier and which is more difficult to understand and learn.

Serious Games and declarative knowledge: Serious Games for the transfer of declarative knowledge are used in many different areas. Especially learning processes that are highly repetitive, such as memorizing vocabulary when learning a new language, can be made effective and interesting in this way. There are games for learning living and spoken languages like English (Johnson, 2007; Sørensen & Meyer, 2007), but also for learning programming languages (Mitamura, Suzuki, & Oohori, 2012; Zapušek & Rugelj, 2013). Serious Games are also used in the natural sciences (Dele-Ajayi, Sanderson, Strachan, & Pickard, 2016). In the field of physics the project 'Ludwig' (*Ludwig*, 2013) was developed. This game for children from 11 years of age deals with renewable energies. Together with robot Ludwig, the player is supposed to supply the earth, on which no fossil fuels are available, with electricity. For this, knowledge about wind power, water power or solar energy must be acquired and applied in puzzles.

Serious Games and procedural knowledge: Many applications that are supposed to transfer procedural knowledge use VR. A particular strength is that the training or preparation can take place independent from the user's location. For example, training for a new job can be done from home (Van Wyk & De Villiers, 2009). Assembly instructions can be also explained this way. Palmas et al. (Palmas et al., 2019) explains in a gamified VR application the correct procedure for building a drum set.

Especially in the field of medicine and health, Serious Games have been developed that transfer procedural knowledge. The already mentioned games 'Bronkie the Bronchiasaurus' or 'Packy and Marlon' explain the exact use of the asthma inhaler, as well as the sequence and interrelationship of food and insulin intake to influence the blood sugar level.

The project 'Emerge' (Chon et al., 2019) is aimed at medical students and teaches both declarative and procedural knowledge. The game simulates typical events in an emergency room. The player takes over the role of the doctor, who is responsible for both management and medical care. He has to decide which patients are treated first. Furthermore, he makes the exact diagnosis (declarative) and determines the further processes (procedural) necessary to treat the patient. The game was tested with 140

medical students from the 5th to 12th semester. For the study they were divided into four groups (n=35), each playing different scenarios. The declarative and procedural knowledge of the subjects was checked with a questionnaire before and after the game. The proportion of correctly answered questions in the area of declarative knowledge increased from the mean value of 60.4% (SD 16.6) to 76.0% (SD 11.6). With regard to procedural knowledge, a significant positive effect could only be measured in one group.

5. DragonTale - a Kanji Game

In the following chapters, Serious Games are presented that deal with different topics from the field of cultural heritage. Different combinations of Game Mechanics are used to convey declarative and procedural knowledge to the player.

Figure 5.1.: *DragonTale* - Learning Japanese Kanji (Plecher et al., 2018)

First we introduce the Serious Game *DragonTale*, which is dealing with the intangible cultural heritage of Japan. In focus of the game is the story of the little dragon Ryu (see Figure 5.2) and the main character Yuni (see Figure 5.3), which is controlled by the player. Together they experience adventures and have to solve puzzles or fight against enemies. The communication between the two is difficult, since Ryu only knows Kanji, the language of the dragons, which Yuni and as a consequence the player now have to learn. Special attention was paid to the Game Mechanics *Story* and *AR* in this game.

This game's aim is a low-threshold start in learning the Japanese language. The project has evolved over several years with multiple guided student projects. The prototype was developed during the Master Practical Course Games Engineering together with Monika Wintergerst, Stefan Kreisig and Janosch Kindl. The project was supported by Christian Eichhorn, who has been learning Japanese for several years. The results of the first iteration were presented as a Work in Progress Paper at CHIPlay 2018

in Melbourne (Plecher et al., 2018). Further developments with the support of Ilcin Ötztürk (Ötztürk, 2020) and Alexander Pongratz (Pongratz, 2018, 2020) introduced new content, but also implemented feedback. A final study with a sufficient number of participants was planned, but had to be postponed due to the ongoing Covid-19 pandemic. The project is focused on the following research questions:

- **Q1: Can the proposed Serious Game successfully transfer knowledge about the Japanese Kanji?**
- **Q2: What impact does AR have on the transfer of knowledge in a Serious Game about Japanese Kanji?**

Figure 5.2.: Ryu[1]

Figure 5.3.: Yuni[2]

5.1. Related Work

Various digital resources are already available for learning Japanese or Kanji. Applications for the smartphone are popular, so that learning content can be learned or repeated on the move and independent of location. Gamification is often used for this purpose. The exercises take the form of small puzzles in 2D, where points and badges can be collected. An synopsis always shows the user's current progress as well as the next milestones to be reached. Examples for these applications are: 'Duolingo' (*Duolingo*, 2011), 'Memrise' (*Memrise*, 2010) and 'Mindsnacks' (*Mindsnacks*, 2015). Our project goes beyond these gamified solutions and offers a complete game for the use on mobile devices (preferably tablets), to teach the basics of the Japanese language with special focus on Kanji. The learning content is closely interwoven with the story of the game,

[1] https://assetstore.unity.com/packages/3d/characters/micro-dragon-fino-8371[(last access 2021/02/01)]
[2] © Unity Technologies Japan/UCL

so that progress in the game is only possible by simultaneously improving the language skills.

There are already examples of Serious Games that deal with the Japanese language. Slime Forest Adventure (LRNJ, 2006) is a role-playing video game, which was developed by LRNJ (LeaRN Japanese). Different enemies attack the player with Kanji, which symbolize powerful spells. The player can only neutralize them by typing in the meaning of the Kanji. In this way, up to 2000 different Kanji can be learned. Another example is Kanji Corporation (*KanjiCorporation*, 2015), which is played on the smartphone. The goal is to build and run a company that produces images of Kanji. Therefore, as one one of the main tasks the player decides whether these pictures represent the meaning correctly. In 120 levels 800 Kanji are presented and can be learned and repeated. The games in the Learn Japanese to Survive (*Learn Japanese To Survive!*, 2016) series take a similar approach to teaching hiragana and katakana in addition to Kanji. 'Slashcards Japanese' (*Slashcards*, 2017) additionally uses other interesting game mechanics. Here the player must not only translate the Kanji, but also be able to write it himself. A further component is the competitive and cooperative multiplayer mode, which provides additional motivation.

'Hanjamaru' (Baek, Xu, Han, & Cho, 2015) was developed to teach Korean students the Chinese characters (Kanji) in a playful way. 'Kawaii Nihongo' (*Kawaii Nihongo*, 2014) takes a different approach. Here the popular genre of Japanese Manga and Anime is combined with language learning. A complex RPG game that merges story and learning content is 'Koe' (声) (*Koe*, 2014). The player accompanies his virtual character to school and the teaching material is then applied in the world of history. Many different mini-games and puzzles offer variety in the repetition of what has been learned. 'Koe' relies on a complete 3D world in which the story takes place. The progress in the story is also linked to the acquisition of knowledge.

The use of AR in connection with Serious Games for the Japanese language could not be found in the previous games. An example of this is the App MondlyAR (*MondlyAR*, 2016). Several languages including Japanese can be learned with this app. In this case AR is used in combination with Gamification. A virtual conversation partner can be augmented to any straight surface with the help of the display of a smartphone or tablet. In the same way, virtual objects can be displayed to represent the word, that needs to be learned.

So far, there is no complete Serious Game in combination with AR that deals with Kanji. Wagner and Barakonyi (2003) presented a prototype of the Serious Game 'AR Kanji'. This round based game is designed for two players. The players sit or stand at a table with ten different cards with Kanji and a handheld device for each player. In each round, the device displays an English word, which describes an object. The next step for the player is to find the translation of the word and as a consequence the corresponding Kanji. If the correct card is held into the camera of the handheld device, the translation is displayed in the form of a matching virtual object and the player gets one point.

For learning other languages AR applications or Serious AR Games can be found. Barreira et al. (2012) developed the game MOW (Matching Objects and Words). The

goal was to teach simple English terms to primary school children with Portuguese as their mother tongue. Two different stacks of cards and markers were used. One of them showed pictures of animals, the other one the corresponding vocabulary. The player has to form the correct pairs and hold both markers in the camera. When correctly assigned, a 3D object of the corresponding animal was displayed on one of the markers. Otherwise a signal was played, which should indicate the made mistake. All mentioned games, which deal with the teaching of the Japanese language, are summarized again in Table 5.1.

Apps and Games for Learning Japanese					
	Game Elements				
	3D	Story	Turn-based	AR	Myth
Slime Forest Adventure	X	X			
Kanji Corporation		X			
Learn Japanese to Survive!	X	X			
Slashcards: Learn Japanese	X				
Hanjamaru		X			
Kawaii Nihongo		X			X
Kanji no Owari	X	X	(X)		X
Koe (声)	X	X	X		(X)
MondlyAR	X			X	
AR Kanji	X		X	X	
DragonTale	X	X	X	X	X

Table 5.1.: Comparison of Apps and Games for Learning Japanese

5.2. Game idea

DragonTale is intended to combine all of the above elements of existing games and applications for learning Kanji and getting started with the Japanese language. For example, fighting opponents by entering or selecting the corresponding Kanji is very popular in these kind of games. We took these elements and linked them to the story of the two protagonists Yuni and Ryu. Additionally, AR was used to make classical learning with flashcards more interesting and to create new connections between Kanji, its meaning and the corresponding object.

We based the design of the Serious Game on the ARCS model (Keller, 2009) (see section 2.2.2):

- **Attention** - The player should be attracted by the story, which is based on parts of Japanese mythology. Furthermore, AR is used in the further course of the game to trigger the user's attention and curiosity.

- **Relevance** - The game is structured in such a way that all actions are comprehensible to the player. Likewise, the game's location in a Japanese-style setting and its relationship to Japanese mythology shows a connection between learning and game content. The reason for learning is also supported by the story, especially the communication with the dragon Ryu.
- **Confidence** - All puzzles and tasks are designed to be solved by the player with reasonable effort. The necessary learning content has been provided beforehand and can also be called up and repeated by the player at any time. NPCs also offer assistance on request.
- **Satisfaction** - Every action leads to direct feedback. Solving the puzzles leads to the acquisition of new Kanji, new information, progress in the story and finally to new levels with new areas to explore.

In the following we first look only at the learning content and then at the gaming content in connection with the learning elements:

Figure 5.4.: *DragonTale* - using the virtual joystick (Plecher et al., 2018)

5.3. Learning Content

Those who have set themselves the goal of learning the Japanese language have to master a number of challenges. The Japanese Language uses three different writing systems: Hiragana (ひらがな), Katakana (カタカナ) and Kanji (漢字). The first two are of Japanese origin and together comprise a total of 92 characters. Kanji, which actually

have a Chinese origin, are the equivalent of whole words. These consist of about 200 radicals (bushu), which transfer their individual meanings to the Kanji. There are several thousand of them, but 2136 are used in everyday life. This number poses great problems for learners of the Japanese language regardless of their nationality. (Hadamitzky, 2012)

To master Kanji correctly, the learner must acquire the following knowledge:

- Knowledge of about 2000 Kanji
- The correct stroke order when writing the Kanji
- Different emphases lead to different meanings
- Kanji can be combined to other words (composita/jukugo)

5.4. Serious Game Mechanics

The game *DragonTale* is designed for beginners and thus focuses on Kanji of proficiency level N5 (*JLPT*, 2012), which is the easiest level. These are everyday terms, which can also be used to form compound words. The Serious Game mechanics for teaching the learning content about the stroke order and the composita consists of mini-games (Game Mechanics (GM)) in combination with different Learning Mechanics (LM). A summary of the mechanics, the respective implementations and the triggered aesthetics is shown in Table 5.2.

DragonTale			
Game Mechanic	**Learning Mechanic**	**Implementation**	**Aesthetics**
Minigames	Repetition, Reflection, Analysis, Feedback	Drawing-Game, Fight, AR-puzzles	Challenge
AR	Identification, Objecti-fication, Observation	AR-Puzzle	Sensation
Story & Role Play	Motivation	Story, Characters	Narrative
Questions & Answers	Feedback, Repetition	Usage of Kanji in Quests	Challenge

Table 5.2.: LM-GM Analysis of DragonTale according to Arnab et al. (2015) augmented with aesthetics from the MDA Model (Hunicke et al., 2004)

Drawing Game (Stroke Order): In contrast to other characters, e.g. hieroglyphs, the stroke order of Kanji has to be observed when writing a character. For learning and practicing the stroke order, the so-called 'drawing game' (see Figure 5.1) is implemented. As soon as a Kanji is to be unlocked in the main game or used to solve quests, the 'drawing game' starts. Here the player must draw the individual strokes of the displayed Kanji in the correct order with his finger. If the action is not executed correctly, the

Figure 5.5.: Battle System (Plecher et al., 2018)

player gets feedback by an animation showing the solution. Through repetitive practice *(LM: Repetition)* in combination with appropriate response and analysis *(LM: Feedback)*, the player remembers over time the correct order. This Game Mechanic triggers the Aesthetics *Challenge*, especially with complicated Kanji. In the game, analogous to the flow model (see subsection 2.2.4), care is taken to constantly alternate the use of the Kanji so that the perceived emotion of the player does not turn into boredom due to an underchallenge.

Quests and Battles (Usage and Meaning of the Kanji): The unlocked Kanji can be used for quests but also in the battle system. After selecting the desired Kanji, the drawing game is started. If the correct order of strokes is executed correctly, Ryu performs the desired action. In the fight Ryu competes against the respective opponent (see Figure 5.5). Depending on the selected Kanji from the inventory, the dragon directly executes an attack action. When the opponent attacks, an indication of the best defensive reaction is displayed. The player then has 5 seconds to select the correct Kanji. Successful attack actions result in a reduction of life points. The first player to run out of life points loses the fight. This game mechanic is connected with the Learning Mechanic *Repetition*, because here the meaning of the collected Kanji is repeated. Especially because of the short reaction time in the defensive actions, the fight as a whole triggers the Aesthetics *Challenge*.

Figure 5.6.: Marker printed on a beer coaster (Plecher et al., 2018)

AR Mini-Games: In the Japanese language, different words can be formed by joining together combinations of Kanji (jukugo). The word Kanji 漢字 itself is formed by two Kanji. 漢 means Chinese and 字 stands for character. This phenomenon was also integrated into *DragonTale* by using AR and Mini-Games as Game Mechanics.

In addition to the tablet, the player also has a certain number of printed Kanji that have been attached to coasters (see Figure 5.6). At a certain point in the game the camera of the tablet is activated and the player is asked to form a certain jukugo. To solve the task the player has to place two or three markers with the corresponding Kanji in the correct order and point the camera at them. Figure 5.7 shows this procedure using the word Japan 日本, as an example. This is formed from the Kanji 日 (sun) and 本 (origin). On the left image, the augmentations are presented on the individual markers. Since the order is not yet correct, a red line is shown between these two. The right image represents the correct solution. The matching Kanji in the correct order result in the land of the rising sun. Consequently, the virtual object of the Japanese flag is augmented on the composite markers. Another example would be: 火山 *(vulcano)* consisting of the characters 火 *(fire)* and 山 *(mountain)*. *AR* as a Game Mechanic helps to better present the learning content. By augmenting the meaning of the corresponding object directly onto the markers with the Kanji, the player can easily recognize the correlations *(LM: Identification, Objectivation)*. AR triggers the Aesthetics *Sensation*, especially for players who have not used this technology before. In order to avoid overload, additional red or green connecting lines are drawn between the Kanji, which are suitable for forming a jukugo.

Story: The *Story*, which we will discuss in more detail in the next section, is an important Game Mechanic in *DragonTale*. The Octalysis framework (see section 2.1.5) shows that human curiosity is a motivating factor. Furthermore, this Game Mechanic addresses the Aesthetics *Narrative* and *Fantasy*. The interest in the development and the end of the story are motivators *(LM:Motivation)* that make the player progress in the game.

Figure 5.7.: AR Compositum (jukugo) - 日本, (Japan) (Plecher et al., 2018)

5.5. Story and Level Design

Kanji	Meaning
火	Fire
水	Water
上	Up
木	Wood

Table 5.3.: Learning Content - Level 1: Kanji

Level 1: In the first level, the player explores the Japanese-looking surroundings together with Yuni. In order to save her family's small fishing boat from a storm, Yuni has to go to the beach. There she finds a mysterious egg from which the dragon Ryu hatches. Yuni has never encountered such a creature before and thereupon seeks help from the village elder. He explains to her that she has found a magical dragon. However, its special powers can only be evoked by specific characters from the language of dragons (Kanji). Together with Ryu, Yuni goes on a search in the village for records about the language and the history of the dragons. In the temple, they discover three scrolls that tell her the characters for fire 火, water 水 and up 上. To unlock these Kanji the drawing game is triggered to learn the correct order of strokes. After leaving the temple, they immediately have the opportunity to use their newly learned knowledge. Lightning has struck a tree. The fire must be extinguished before it can reach the houses nearby. The player must now select the correct Kanji for water in the inventory so that Ryu can extinguish the fire. If the action is performed successfully, the Kanji 木 for wood will reveal itself to the two. Yuni decides to help Ryu finding his family. In order to proceed in the story and in learning Kanji they have to repair a destroyed wooden bridge with the help of the now unlocked Kanji to enter the second level.

Level 2: After crossing the bridge, Yuni and Ryu reach a forest. There they meet a stranger who is trying to make a fire to grill meat. Since the stranger has lost his matches,

Kanji	Meaning
肉	Meat
森	Forest
林	Grove
一	One
二	Two
三	Three

Table 5.4.: Learning Content - Level 2: Kanji

Yuni uses the Kanji 火 for fire she learned to help him. This action unlocks the Kanji 肉 for meat. Upon realizing Ryu's magical powers, the stranger is eager to take possession of this dragon. When Yuni refuses to give up the dragon, a combative confrontation ensues (battle system). For attack and defense the Kanji for fire 火, water 水 and wood 木 are used. When the stranger is defeated, he takes flight under threat of revenge. Yuni and Ryu follow a voice deeper into the forest and unlock the following Kanji: 一 (one), 二 (two), 三 (three), 森 (forest) and 林 (grove).

Kanji	Meaning
花	Flower
見	View
山	Mountain
五	Five
六	Six
七	Seven
八	Eight
九	Nine
十	Ten

Table 5.5.: Learning Content - Level 3: Kanji

Level 3: In the forest, Yuni and Ryu discover a house that looks abandoned. A large stone in the garden in front of the house hides a riddle. Solving the riddle unlocks the Kanji 山 for mountain. Surprisingly, the witch Aowabasa suddenly appears before them. She has more knowledge about Kanji and also knows the reason why the dragons have retreated into a hiding place. But she doesn't want to share her knowledge with Yuni. First the protagonists have to fulfill some tasks to gain the witch's trust. Among other things, they must plant a flower (花) and watch it grow (見, view). When Aowabasa is pleased, she reveals several secrets to Yuni. First, she explains that multiple Kanji can be connected. For example, flower (花) and fire (火) can be combined to form the word fireworks (花火). Second, the witch explains the Kanji for the numbers from six to ten. Numbers greater than ten can also be generated by combining the corresponding Kanji,

e.g. ten (十) and one (一) makes eleven (十一). Furthermore, the witch tells that dragons used to live in this area until they were betrayed by humans.

Kanji	Meaning
友	Friend

Table 5.6.: Learning Content - Level 4: Kanji

Level 4: Yuni and Ryu leave the forest again and return to the village with their newly acquired knowledge. They report to the elder what they have found out. In the meantime, the elder has also made inquiries. He suspects that the dragons are hiding on a nearby island, since this island appeared at the same time as the dragons disappeared from the sea. So far, no one had managed to discover their hiding place on the island. Yuni decides to take a boat to the island. Before leaving, the elder praises the friendship that has developed between Yuni and Ryu. At this stage, the Kanji 友 for friend is unlocked. During the crossing Yuni opens up the jukugo water surface (水上) consisting of water 水 and up 上. On the island she discovers after a long search a locked cave entrance. A voice whispers to her that friendship is the key. Thereupon she opens the cave with the Kanji 友 (friend) and enters.

Level 5: There are four pillars in the cave, each of them is representing an AR puzzle. Interacting with one of the pillars the AR Composita Mini-Game for forming four different jukugos starts. The tablet's camera is activated so that the player can combine the markers with the corresponding Kanji, as described earlier in section 5.4. When all four puzzles are solved, an old dragon named Mizuchi appears in the cave. The dragon still speaks the human language and can consequently talk to Yuni. Mizuchi thanks her for saving Ryu. At the same moment, the stranger from the forest appears in the cave with some other men who are supposed to help him take Ryu. Yuni confronts them and another mini-game starts. The henchmen of the stranger are mercenaries. The goal is to pay them a certain amount of money to leave the fight. When all the mercenaries are paid off, the stranger will also withdraw. The exact procedure of the Mercenary Game will be described in more detail in the next section. When the battle is won, the game ends with a final conversation between Mzuchi and Yuni. Through her altruistic efforts on behalf of Ryu, Yuni has convinced the dragon Mizuchi to return to the human world.

5.6. Mini-Games with and without AR

In order to investigate how AR is perceived by the player, the two mini-games of level 5 were implemented in a version with and without AR for the evaluation.

In AR mode the AR Composita Mini-Game was played as already described in section 5.4 with a selection of printed markers with corresponding Kanji. The so-called Mercenary Game uses the same interaction features as the AR Composita Mini-Game.

Figure 5.8.: Mercenary Game without AR (Ötztürk, 2020)

Coins are displayed above the heads of the mercenaries. A gold coin has the value 10 and a silver coin corresponds to the value 1. To pay out the sum, the value must be represented by Kanji. The player uses corresponding markers for the numbers from one to ten. Numbers greater than ten must be represented by the combination of two Kanji (see explanation level 3).

In the version without AR, the Kanji were shown as tiles on the display (see figure 5.8). Analogous to the version with AR, after selecting a Kanji, the corresponding object to symbolize the meaning is displayed. The task is solved by moving the matching Kanji in the correct order from the inventory (at the bottom of the screen) to the designated fields.

5.7. Evaluation

As mentioned at the beginning of this chapter, it was not possible to conduct a larger study to evaluate the research questions due to the Covid-19 pandemic. Instead, in cooperation with Ilcin Ötztürk (Ötztürk, 2020) we did a pre-study with only ten participants in the age group from 18 to 30 with an average age around 23.

For testing the knowledge transfer and the perception of AR we divided the ten participants into two groups:

- **Group A:** 5 participants (3 female and 2 male) played the version with AR;
  no participant had prior knowledge in Japanese;
  the participants had hardly any experience with AR.
- **Group B:** 5 participants (3 female and 2 male) played the version without AR;
  1 participant had prior knowledge of Japanese (Level A1.1).

Because of the pandemic restrictions, the participants played the game individually on their mobile devices at home. All necessary information for playing the game regarding using the virtual joystick and interacting with objects and NPCs were given to the participants. Group A was additionally informed about playing the AR Mini-Games. They had to print the AR markers with the Kanji themselves. After finishing the game both groups filled out a questionnaire. The players had to answer questions about demographics, their experiences with AR (only group A) and with mobile language learning applications as well as their Japanese proficiency level.

To determine the knowledge transfer of each version, participants had to answer questions about Kanji and their meaning. Three different types of questions were used in the questionnaire. In the first four questions, the meaning of a Kanji shown must be selected from four different answer options. In the next six questions (including 2 questions on jukugo), participants have to match the meaning with the corresponding Kanji or combination. Finally, four questions about the numerical system must be answered by drawing the corresponding Kanji.

5.8. Results of the Evaluation

Kanji/(Meaning)	Group A	Group B
肉 (meat)	4/5	5/5
水 (water)	3/5	4/5
上 (up)	3/5	5/5
林 (grove)	5/5	5/5

Table 5.7.: Results of the first set of questions regarding knowledge (matching Kanji and meaning).

Table 5.7 shows the results of the first set of questions. The participants had to match the right meaning to a given Kanji. In group A, four out of five participants selected the right meaning for 肉 (meat). Regarding 水 (water) and 上 (up), three participants were able to give the correct answer. 林 (grove) was identified by everybody in this group. In group B, all Kanji were recognized flawlessly by the participants with one exception. 水 (water) was not correctly assigned by one participant.

The results of the second set of questions are shown in Table 5.8. The participants had to match the right Kanji to a given meaning. Here, both groups hardly made a mistake. Only two participants in group A had problems with matching firework and 花火.

Table 5.9 shows the results of the third set of questions. The participants had to draw the right Kanji to a given meaning. In both groups all members were able to draw the right Kanji for three (三). In group A, only one participant was able to draw the Kanji for seven, in group B there were three. Both groups had equal results for the last two questions. One participant each could draw the Kanji for nine (九) and two participants for sixteen (十六).

Meaning/(Kanji)	Group A	Group B
view (見)	5/5	5/5
fire (火)	5/5	5/5
forest (森)	5/5	5/5
firework (花火)	3/5	5/5
volcano (火山)	5/5	5/5

Table 5.8.: Results of the second set of questions regarding knowledge (matching meaning and Kanji).

Number (Kanji)	Group A	Group B
three (三)	5/5	5/5
seven (七)	1/5	3/5
nine (九)	1/5	1/5
sixteen (十六)	2/5	2/5

Table 5.9.: Results of the third set of questions regarding knowledge (Drawing the right Kanji).

5.9. Analysis

We analyze the results based on the research questions:

- **Q1: Can the proposed Serious Game successfully transfer knowledge about the Japanese Kanji?**

Even if we only look at the results of a small preliminary study, we can at least derive insights regarding the first research question from it. The following learning content was integrated into the game:

- 11 different Kanji including their correct notation.
- 4 compound words (jukugo)
- 10 Kanji for the numbers from 1 to 10. By combining them, the number range from 1 to 19 can be covered.

In the questionnaire, 13 questions were asked about this learning content. Group A was able to answer 72% of them correctly. Group B was slightly better with 84%. However, there was one participant with prior knowledge in this group. In summary, DragonTale has the potential to transfer knowledge to the player. But this needs to be further investigated in a bigger study.

- **Q2: What impact does AR have on the transfer of knowledge in a Serious Game about Japanese Kanji?**

In this non-formal study, AR was not observed to additionally enhance the knowledge transfer of the Serious Game. Group B even scored slightly higher. In the questionnaire, both modes were rated as intuitive. Except by one participant from group A, who had technical problems using AR.

One reason for this is that the testing could not be conducted at the university due to the pandemic restrictions. The participants used their own and thus different devices. Furthermore, they also had to print the markers themselves, which may also cause problems. Technical obstacles as well as too high cognitive or skill-based challenges lead to excessive demands and frustration. As a result, players are no longer in the flow and are no longer motivated to engage with the learning content. A statement on the second research question can only be provided by the main study, which can hopefully be carried out soon and under the same conditions for all participants.

5.10. Future Work

How can *DragonTale* be improved in further iterations?

Game content: When the prototype of this Serious Game was presented at CHIPlay 2018 in Melbourne, the embedding of the learning content in the adventure story was particularly appreciated. The story will be expanded and enriched with more Kanji in the future. The Aestethic *Narrative* should continue to motivate the player.

Learning content: Linguistic and mythological elements from the intangible Japanese cultural heritage have been used so far. Further information about still maintained traditions, festivals or manners could be added. Furthermore there is the possibility to include Hiragana and Katakana. Small implementations have already taken place here. This way DragonTale can be used even better for learning the Japanese language. Adding audio would be very helpful, so that in addition to the stroke order and the meaning the correct pronunciation can be learned. The study, which had to be postponed, will of course be rescheduled. It is also planned to include students who are learning Japanese at the TUM Language Center at level A 1.1 or A 1.2 in this study.

Technical improvements: The drawing game is basically a good idea as it conveys the learning content appropriately. However, tracing the stroke order on the tablet with the finger could be replaced by more technically sophisticated solutions. The Manomotion SDK *Manomotion* (2015) has already been tested for this use. Here, the positions and gestures of the hand are tracked and analyzed based on camera images. Hence, it is possible to draw the Kanji with the finger in the air or on the tabletop.

5.11. Summary

DragonTale is a story-based single-player Serious Game, that deals with Japanese cultural heritage. The player accompanies Yuni and the little dragon Ryu through a japanese themed game world. Together they experience adventures and have to solve puzzles or fight against enemies. The communication between the two is difficult, since Ryu only knows Kanji, the language of the dragons, which Yuni and as a consequence the player now have to learn. The special characteristics of this writing system, such as stroke order or even combinability, were integrated into the main game through minigames. To investigate the effects of using AR, two different game modes (with and without AR) were implemented.

Due to the Covid-19 pandemic restrictions, it was only possible to conduct a preliminary study which nevertheless provided many useful insights. Based on the results we could notice that the game can transfer knowledge about Kanji to the player. An improvement in knowledge transfer through AR could not be determined. Since the study could not be conducted at the university, the participants had little experience in using AR. As a result, technical problems could not be solved by the participants themselves. Due to the decentralized conduct of the preliminary study, the participants had to rely on their own devices. It is also possible that the technical difficulties led to excessive demands (see Flow, section 2.2.4) and consequently to less knowledge gain.

The next two chapters address some of these design decisions of *DragonTale* in other learning contexts. Changing contexts provide clearer options to focus on specific design issues since they may have a stronger impact in one context than in another.

6. Oppidum - A Serious-AR-Game about Celtic Life and History

Figure 6.1.: *Oppidum* - augmented boardgame (Gomm, 2020)

"The year is 50 BC Gaul is entirely occupied by the Romans. Well not entirely...
One small village of indomitable Gauls still holds out against the invaders.[1]"

This is the well-known opening of all Asterix comics about a rebellious village of Gauls. As Caesar already mentioned in his famous "Commentarii de bello Gallico" ("Commentaries on the Gallic War"), Gauls (lat. Galli) is the Roman appellation for the Celtic tribes in Gaul (lat. Gallia).[2] Obviously, these comics do not have a purpose to teach history; however, the funny adventures take place in the ancient world, and consequently, they trigger the reader's interest. In addition, these comics can be used in an educative way for language training, as Asterix is translated in nearly all languages including

[1] Uderzo, A., Goscinny, R.: Asterix the Gaul. 1961.
[2] Caesar, C. I., C. Iulii Caesaris commentarii de bello Gallico, Liber I, 50: "[...] qui ipsorum lingua Celtae, nostra Galli appellantur."

dialects, as well as "dead" languages, such as Latin or Ancient Greek. Therefore, by reading these comics, people can enjoy the mixture of fun and learning. By applying this approach to computer games, we developed a Serious Game in combination with AR, referred to as Serious-AR-Game, which is entertaining to play and, simultaneously, is able to share knowledge about the cultural heritage of the Gauls also referred to as Celts with the players. We want to present our game *Oppidum*, which is named after the archaeological term for a Celtic village. It focuses on the life and history of the Celts during the Iron Age in Europe starting from approximately 800 BC until 1 BC.

Our goal was to create a Serious-AR-Game about the tangible and intangible cultural heritage of the Celts. Common elements of boardgames (see Figure 6.1) were used in a new way to transfer desclarative and procedural knowledge (see section 4.2) to the player. Together with Annette Köhler (Köhler, 2016), the first prototype was developed, containing the basic game content and AR interactions. Alex Bröker (Bröker, 2017) and Konstantin Gomm (Gomm, 2017) added the multiplayer mode with their work in another iteration. The status of the project so far was presented at the GALA conference 2019 in Athens (Plecher, Eichhorn, Köhler, & Klinker, 2019). Konstantin Gomm (Gomm, 2020) also helped to implement the collected feedback in his master thesis and to conduct the final comparative study to evaluate the effects of single- and multiplayer mode.

During the design process of the proposed game called *Oppidum*, we investigated the following research questions:

- **Q1: Can the proposed Serious Game transfer knowledge about the Celtic life and history to a player?**
- **Q2: What effect does a competitive multiplayer mode have compared with a single-player mode on learning motivation and learning outcomes?**

6.1. Related Work

Both AR and (Serious) Games have already been applied to cultural heritage individually as well as in combination. There is a plethora of work done in the field of AR for cultural heritage (Bekele, Pierdicca, Frontoni, Malinverni, & Gain, 2018); therefore, we list several examples related to different topics. A notable example of utilizing AR in archaeological sites is *Archeoguide* (Vlahakis et al., 2002), aimed to augment virtual reconstructions of temples on the corresponding ruins in ancient Olympia. The other well-known example is the *Life Plus* (Papagiannakis et al., 2002) project realized in Pompeii, that has been conducted to revitalize the excavations and showed virtually the Roman's life that had ended in August 79 AD as a result of the eruption of Mount Vesuvius.
Furthermore, AR can be widely implemented in museums. These applications are utilized to guide the visitors through museums, for example, as in the Louvre Museum (Miyashita et al., 2008), or can be used to augment the exhibits with virtual information for explanations or reconstructions (Plecher, Wandinger, & Klinker, 2019). Gervautz and Schmalstieg (Gervautz & Schmalstieg, 2012) have stated that AR can be

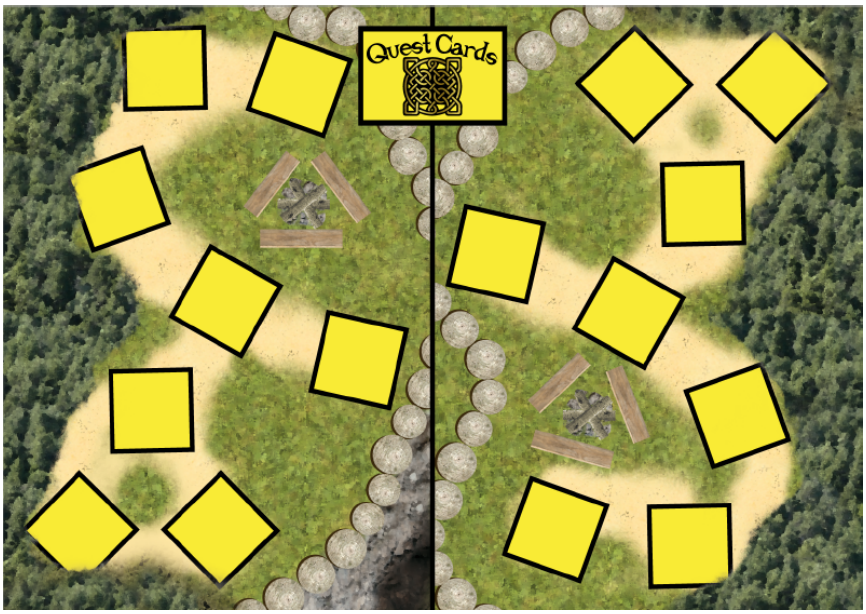


Figure 6.2.: Game Board (Gomm, 2017)

used to revitalize historical events and offer interactive learning without modifying real exhibits. If Serious Games are used for cultural heritage, they are often dealing with tangible objects (Anderson et al., 2009).

AR is also a great support in the teaching of Celtic history. The Franziskanermuseum in Schwenningen presents visitors with a real Celtic burial chamber. Unfortunately, only a few fragments of the original grave goods have been preserved. Starting in the summer of 2021, the *Project GeheimnisGräberei* (2021) will allow visitors to take an augmented look inside the tomb as it may have looked. All virtual paraphernalia have been augmented into the tomb and will then be available for inspection. The project will also include game elements, so the AR view will have to be unlocked first.

The Museum of Celtic Heritage in Salzburg already uses an application called *The Speaking Celt* (Breuss-Schneeweis, 2016). The visitor scans certain markers at selected locations and exhibits. A virtual Celt then appears in the AR view, acting as a museum guide and passing on information to the visitor.

6.2. Life and History of the Celts

When dealing with Celtic culture, there is the problem that the Celts left almost no written records and sources of their own. Therefore, in addition to archaeological findings, research must rely on the works of Roman and Greek authors such as Herodotus, Diodorus, Caesar and Strabon. Furthermore, the Celts do not represent a nation. It is rather a term for several tribes that had similar traditions and Celtic dialects. The Celts were sedentary and subsisted mainly by raising cattle and farming. The cattle served

them as a source of food for meat and milk, as draught animals in the cultivation of arable land and as a source for the production of leather goods. The Celts were famous for their knowledge of mining and metallurgy. By building tunnels they were able to mine salt and metals such as copper or iron in large quantities. They used the latter to create tools and weapons, which were even used by the Romans. The Celtic products were traded all over Europe through a widespread trade network. This also enabled them to import wine or glass. (Maier, 2012)

6.3. Game Design

The Serious-AR-Game *Oppidum* is divided into three parts, just like Gaul at the time of Caesar. First, it is a classic digital construction and management game, in which the player takes care of building a Celtic village. The second part consists of the use of AR. This technology makes it possible to include analog game elements such as a game board (see Figure 6.2) and cards, which serve as markers (see Figure 6.3), in order to place the virtual buildings on them (see Figure 6.4). The third part is the serious content which consists in the fact that all buildings were modeled after archaeological reconstructions. With the help of AR, the buildings can be inspected from the outside and inside. In addition, further information material is offered in the form of text and images.

Figure 6.3.: Building Card: Marker (Plecher, Eichhorn, Köhler, & Klinker, 2019)

Oppidum was designed as a game for one or two players and implemented with Unity[3]. Vuforia[4] was used for the AR technology.

The player uses a tablet with the *Oppidum* application and places the game board and cards on a table. By using the tablet's camera, it is possible that the game board and markers are shown on the display along with static elements such as the status and menu bar. The game is turn-based, allowing for a structured flow even in multiplayer mode. In each turn, a player can perform two possible actions - indicated by action

[3] `https://unity.com` [accessed 2021-02-01]
[4] `https://www.ptc.com/en/products/augmented-reality/vuforia`[accessed 2021-02-01]

Figure 6.4.: Markers with augmented buildings (Plecher, Eichhorn, Köhler, & Klinker, 2019)

points. Thus, houses can be built, technologies can be researched or a so-called QuizWar can be started. At the beginning, a small amount of resources like wood or food is available. The current stock is displayed in the status bar (see Figure 6.5 (left)).

A tutorial explains to the player the exact process and possible interactions in the game. For beginners, hints and explanation can also be accessed at the beginning of each round. The player has to collect seven victory points to win the game (see Figure 6.5 (right)). These points can be achieved in various ways, such as building houses, collecting rune stones and successfully completing the QuizWar. In multiplayer mode, the player who outperforms the opponent in the QuizWar earns the victory point.

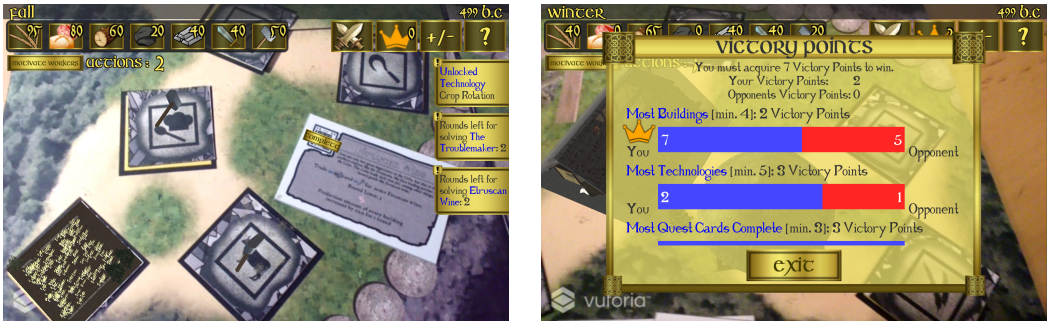


Figure 6.5.: Resource overview, status messages and game buttons (left) and Collection of victory points (right) (Plecher, Eichhorn, Köhler, & Klinker, 2019)

6.4. Serious Game Mechanics

In the following, we describe the most important elements of the game individually and present their importance both for game play and for conveying information. For classification, we use the LM-GM model (Arnab et al., 2015) in combination with the MDA framework (Hunicke et al., 2004). A summary of the mechanics, the respective implementations and the triggered Aesthetics is shown in Table 6.1.

Oppidum			
Game Mechanic	**Learning Mechanic**	**Implementation**	**Aesthetics**
AR (Virtual Information)	Identification, Objectification, Observation	Buildings in AR	Sensation, Discovery, Curiosity, Immersion
Quest, Rewards/Penalties	Action/Task, Repetition	Quest Cards	Challenge, Mastery
Collecting	Discovery	Collecting Rune Stones	Discovery, Curiosity
Questions & Answers	Feedback, Repetition	QuizWar	Challenge, Mastery
Competition	Participation, Motivation	Multiplayer	Fellowship

Table 6.1.: LM-GM Analysis of *Oppidum* according to Arnab et al. (2015) augmented with aesthetics from the MDA Model (Hunicke et al., 2004)

6.4.1. Buildings

There are eight different building types in total in this game. These include Crop field, Bakery, Stable, Woodchopper, Coal Kin, Mine, Forge and Druid. When players decide to erect one of these buildings, they select the corresponding building card (marker) and place it on the game board. The tablet's camera then scans the marker. In this way, the application recognizes which building is to be constructed. If all the necessary resources are available, the construction can be started by pressing the corresponding button. Depending on the building, the resources required for the construction differ in type and quantity. The construction time can be one or more rounds. When the desired building is constructed, it is augmented on the corresponding marker and can be viewed by the player. In addition, from this moment the building takes over its task in the production chain (see Figure 6.6).

For example, the Crop Field produces crops, which are converted to food in the Stable or Bakery. The food is necessary to supply the other buildings in the production chain. The Woodchopper can deliver wood to the Coal Kiln. The coal produced there is then processed in the forge together with the iron from the mine into weapons or tools.

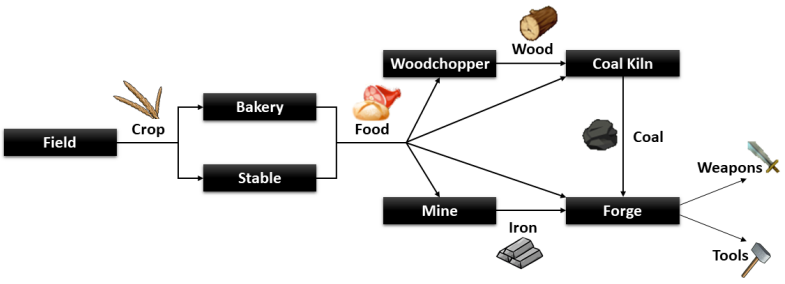


Figure 6.6.: Resources and buildings in *Oppidum* and their interrelationships between each other (Plecher, Eichhorn, Köhler, & Klinker, 2019)

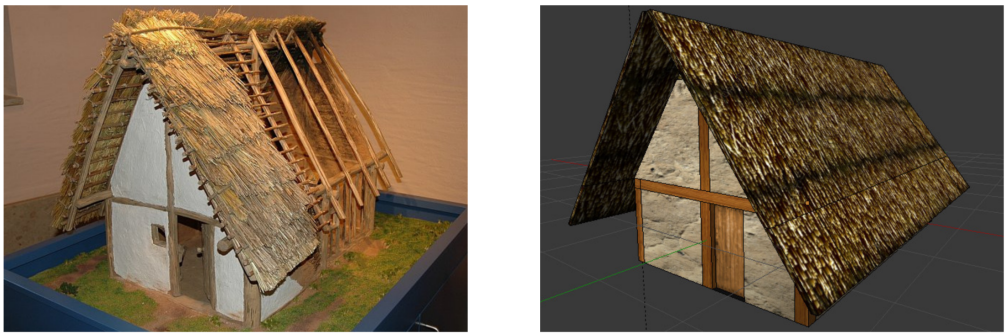


Figure 6.7.: Historically accurate model of a Celtic building (Museum für Archäologie und Frühgeschichte Gutenstetten, Germany) (Gutenstetten, 2008)

These virtual buildings are the central game element and simultaneously combine real elements of the classic board game with the digital application. But they also connect the entertaining game with the learning content. All houses are modeled based on archaeological reconstructions (see Figure 6.7). In this way, the player is provided with information and knowledge about the tangible cultural heritage. The historically correct production processes and procedures within the village symbolize the division of labor and the respective importance in the life of the Celts. Thus, procedural knowledge about the Celts is presented to the player.

Further literal insights are provided when the distance between the tablet's camera and the marker is reduced. The roofs of the houses become transparent during this action and allow the players to look inside (see Figure 6.8) and to discover everyday objects or items necessary for production. Clicking on them opens information panels with declarative knowledge in the form of text and images, which offer further explanations. The player should look carefully, because this information will be needed in the further course of the game (see subsection 6.4.4). The positioning of the houses in relation to each other has an influence on the manufacturing process or on the production rate of the individual manufacturing buildings (see Figure 6.9). For example, if a bakery and a mine or a coal kin and a forge are placed next to each other, the production rate in

Figure 6.8.: Exploring the interior of a building, visible if the player moves closer to the building (Plecher, Eichhorn, Köhler, & Klinker, 2019)

the mine or the forge will increase due to short transport distances. In the AR view, short transport routes are represented by green connecting lines and others in red. The buildings can be rearranged at the beginning of each round to optimize certain processes, e.g. due to a drawn Quest Card. To inform the system of the new positioning, the scan process must be started again. By using Vuforia's extended tracking, it is possible to scan the markers in sequence. Otherwise, all markers on the board would have to be captured by the camera at the same time. This becomes increasingly difficult as the game progresses and the number of markers increases. The production rate can also be increased by developing and unlocking technologies. A tech tree is available for each building. For unlocking them, resources and the respective previous technology are needed. After a certain number of rounds the technology is available. Tech trees are a popular game element in this genre. In *Oppidum* all available technologies were actually developed, adopted and used by the Celts in the Iron Age. More historical information about these topics can be found in the technology menu.

Classification: We chose *AR* as Game Mechanic in this case to make it easier for the player to imagine the buildings and objects (LM: *Objectification)*. It is also a better way to make your own observations (LM: *Observation)*. AR can be associated with several Aesthetics. The embedding of virtual information into the real world triggers

Sensation and promotes *Curiosity* to explore the village or the houses individually in more detail (*Discovery*). The possibility to look into the buildings should lead to an increased *Immersion*.

6.4.2. Quest Cards

In addition to the board and the markers, Quest Cards are another tangible game element used in this game. This again establishes the connection between the classic board game and the digital game. Players take these cards from a deck starting in the fifth round. The cards have been shuffled beforehand and stacked face down so that the player receives random cards. The cards contain various tasks to be completed within a certain number of rounds. In the upper left corner of the card there is a so-called VuMark. These symbols are hardly distinguishable to the human eye and thus enable a uniform design. In contrast, with the help of Vuforia, the application can read the information via the camera and thus determine exactly which card the player has drawn and consequently which quest must be completed. Basically, quests can be solved by producing or submitting a certain amount of resources. To achieve these goals, it is often necessary to rearrange the buildings. There are two different types of Quest Cards in the game. If the quest of a gray card is solved, the player receives a bonus (white hat, see section 2.1.5, octalysis), e.g. the increase of the production rate of a certain building. With a black card, on the other hand, not completing the quest results in a negative outcome (black hat, see section 2.1.5, octalysis), such as temporarily disabling a production facility. As Figure 6.10 shows, the Quest Cards also contain a small introductory story. Some of them are based on historical events and facts. Thus, information is passed on to the player in this game element as well.

Figure 6.9.: The production rate of the different buildings is influenced by the distances in between (Plecher, Eichhorn, Köhler, & Klinker, 2019)

Classification: *Quests* are a classic game mechanic. In *Oppidum* they are started by tangibles respectively randomly drawn Quest Cards. To solve each quest, previously learned procedural knowledge about the Celtic village must be utilized (*LM: Repetition, Task/Action*). In most cases, the buildings must be rearranged for this purpose. The challenge is to complete the task in a certain given number of rounds in order to receive *Rewards (GM)* or avoid *Penalties (GM)*. Successful completion of the quest should give the player the feeling of competence and trigger the Aesthetics *Mastery*.

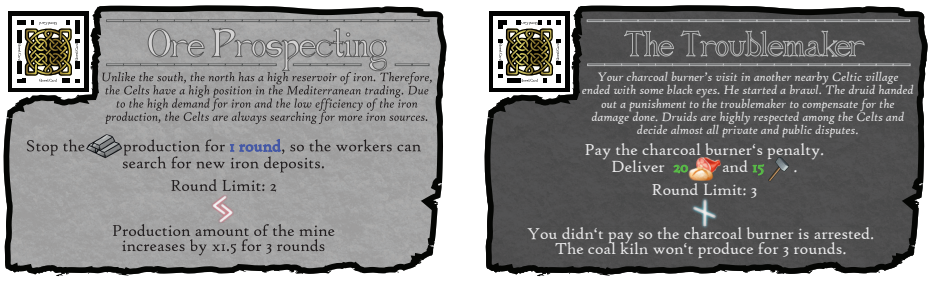


Figure 6.10.: Example for both types of Quest Cards with VuMarks (Plecher, Eichhorn, Köhler, & Klinker, 2019)

6.4.3. Druid and Runes

The druid and the runes are a special feature in the game. The druid's building or grove can be built later in the game, but does not act as a production facility. Its construction allows the player to interact with the druid. The druid was an important part of the Celtic religion in the Iron Age and a respected inhabitant of an oppidum. The Celts did not have their own writing system or characters, so they borrowed them from other languages. Germanic runes are used in the game, as they are associated with mysticism. The player can find and collect rune stones outside or inside the buildings in the AR view. In the course of the game, the player can collect 12 runes and learn about their names, pronunciations and meanings in the so-called rune book (see Figure 6.11). The druid can combine the collected runes to spells, which can either support the own village with bonuses or cause disadvantages for the opponent in multiplayer mode. There is little information about the exact procedures of the cult and the cultic customs of the Celts, so the role of the druid and rune-based spells was integrated into the game through this mystical but of course not historically accurate variant. Nevertheless, in order to impart knowledge with this game element, each player must successfully answer some quiz questions about runes before casting a spell.

Classification: Here the game mechanic of *Collecting* is used. Players must examine the virtual village very closely to find all the rune stones. This is to trigger the Aesthetics *Discovery* and *Curiosity*. The runes found are collected in the rune book. There the player can learn more about their meanings *(LM: Discovery)*.

Figure 6.11.: Rune collection (Köhler, 2016)

6.4.4. QuizWar

So far, the different parts of the game mainly represented the ways to generate knowledge. Of course, a Serious Game also includes the usage of this knowledge. In order to integrate this as appropriately as possible into the gameplay, we invented the so-called QuizWar. This can be played alone or in multiplayer against the opponent, depending on the game mode. The start of this war can be triggered as soon as weapons can be produced in the village and the player still has one unused action point in the current round. In the QuizWar, questions are asked about the information unlocked up to that moment. The players should be motivated to look at the information boards and descriptions. Each QuizWar consists of 6 questions that both players have to solve by choosing the correct answer among four given options. If a question is answered incorrectly, direct feedback is given by highlighting the correct answer. In single-player mode, two-thirds of the questions must be answered correctly to receive a victory point. In multiplayer mode, the player who answered the most questions gets the point.

Classification: In each round of QuizWar, the player is supposed to give the appropriate *Answer* to a *Question*. The questions refer to the information that has been unlocked by all players up to that point. This process includes the Learning Mechanics of *Feedback* and *Repetition*. Answering the questions correctly and finishing QuizWar as the winner is intended to trigger the Aesthetics *Mastery*.

6.4.5. Single- and Multiplayer Modes

In order to conduct a comparative study, it was necessary that the two modes do not contain different or additional game elements. In both modes, the player expands the village turn by turn, draws Quest Cards, inspects the virtual buildings, and rearranges the markers as needed. The main difference is in the QuizWar. In the single-player

mode, it is played without any opponent and is successfully completed when two thirds of the questions have been answered correctly. Here, as with the actions in the respective rounds, possible waiting times are omitted. In our setup for the competitive multiplayer mode, the two players sit across from each other like in a classic board game. Each has a tablet and a set of markers. A local WiFi connection is used so that the applications can also react to the actions of the opponent. For synchronization and management of input and output Ubi-Interact (Weber, Dyrda, Ludwig, & Klinker, 2020) was used. The goal is to reach the necessary seven victory points faster than the opponent.

Classification: The goals of the multiplayer mode are to create a direct *Competition* due to the human opponent. The players should be additionally motivated to deal with the offered information in order to defeat the opponent in the QuizWar and to collect the necessary victory points as quickly as possible *(LM: Motivation, Participation)*. The aesthetic that should be triggered here by the social interaction is *Fellowship*.

6.5. Evaluation

In the main study in collaboration with Konstantin Gomm (Gomm, 2020), we focused on answering the research questions about knowledge transfer and the effects of the different game modes. 24 subjects participated in this study. They were divided into the following groups:

- Group (**M**): 12 participants (male=10; female=2) in the age group 21 to 35 (M=24.1; SD=3.8) played the multiplayer mode.
- Group (**S**): 12 participants (male=11; female=1), in the age group 18 to 26 (M=20.9; SD=2.3) played the single-player mode.

Most of the participants had a general affinity to gaming (Group M: M=5.75, SD=1.36; Group S: M=5.42, SD=1.51) and, on average, a particular experience with AR (Group M: M=4.08, SD=2.31; Group S: M=3.50, SD=1.17) rated on a scale from not-at-all <1> to very much <7>. Group M played the multiplayer mode in pairs and the participants of Group S played the game in single-player mode. In order to determine the knowledge transfer and player experience in the different game modes, the participants had to fill out questionnaires before and after the game. The questionnaires can be found in the appendix. The pre-questionnaire included questions about demographics and various prior experiences regarding AR, digital and classical boardgames.

6.5.1. Measurement of Knowledge Transfer

The pre-questionnaire was used to assess the prior knowledge of the subjects. This was done by asking two questions about the basic interest in the topic and five different detailed questions about the history and life of the Celts. Afterwards, the subjects had

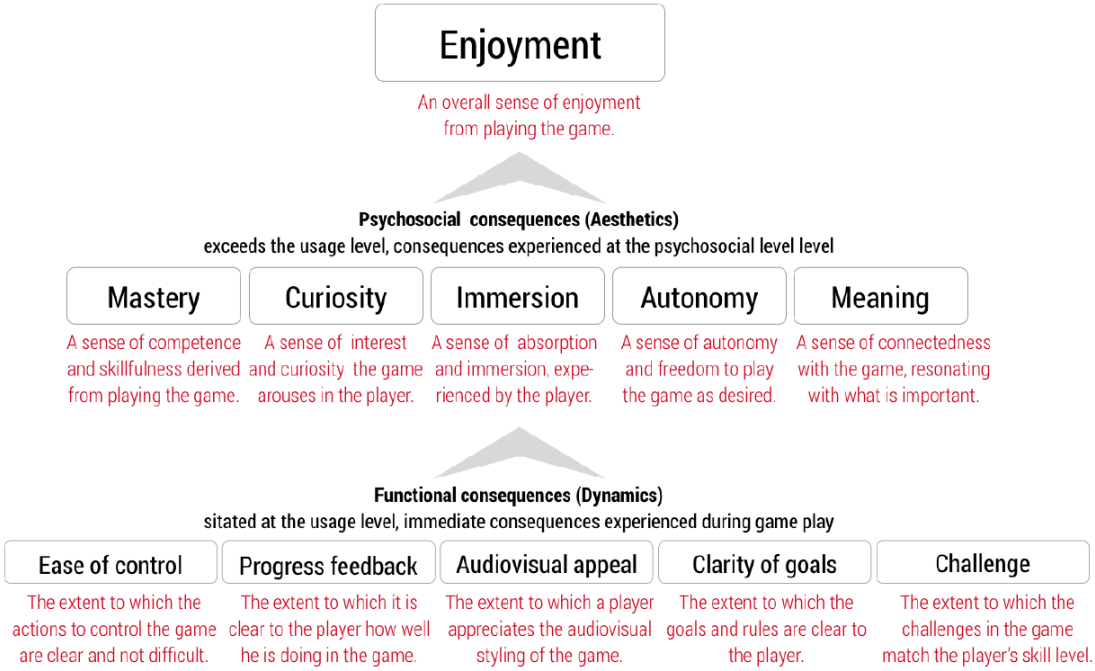


Figure 6.12.: Player Experience Inventory (PXI) (Abeele et al., 2016)

to indicate how confident they were in their given answers. In the post-questionnaire, these questions were asked again to determine changes in knowledge or interest. In addition, five further questions were asked here that related to the information provided in the game.

6.5.2. Mesurement of the Player Experience

To what extent the game mode has an influence on the player experience and thereby also on motivation and learning was ensured by using the *Player Experience Inventory* (PXI) (Abeele et al., 2020). This questionnaire is the main part of the post-questionnaire. Abeele et al. developed this tool to measure player experience at the level of functional consequences (immediate experiences resulting from game design choices) and psychosocial consequences (second-order emotional experiences). As Figure 6.12 shows functional consequences can be associated with Dynamics (Hunicke et al., 2004) (see chapter 3.1) and similarly psychosocial consequences can be mapped to Aesthetics (Hunicke et al., 2004). The questionnaire consists of 10 constructs with 3 items each: *Meaning, Mastery, Immersion, Autonomy, Curiosity, Ease of Control, Challenge, Progress Feedback, Audiovisual Appeal, Goals* and *Rules*. Each item is rated on a seven-point Likert-scale. The average of all associated items results in the score of a construct. Better results are represented by higher scores; Psychosocial consequences can be deduced from the first five constructs *(Meaning, Mastery, Immersion, Autonomy, Curiosity)* and

functional consequences from the remaining five constructs *(Ease of Control, Challenge, Progress Feedback, Audiovisual Appeal, Goals and Rules)*.

6.5.3. Results

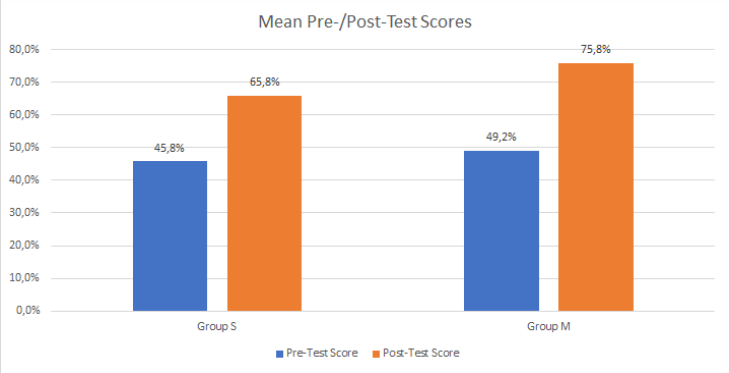


Figure 6.13.: Pre- and Post-test: Knowledge Scores per Group (Gomm, 2020)

- **Q1: Can the proposed Serious Game transfer knowledge about the Celtic life and history?**

Learning Outcome To provide an answer to the first research question, the knowledge scores (correctly answered questions) in the pre- and post-test of both groups were examined (see Figure 6.13). Group M reached an average score of 49.2% (SD=0.22) in the pre-test and could increase the achieved score on average to 75.8% (SD=0.15) in the post-test. Group S reached an average score of 45.8% (SD=0.14) and could increase the achieved score on average to 65.8% (SD=0.17) in the post-test. The increase in values is significant in both groups (Group M: t=2.201, p=0.002; Group S: t=2.201, p=0.002). We can conclude that *Oppidum* has successfully transferred knowledge about the cultural heritage of the Celts to the player.

But to what extent did the game change the players' self-assessment of their interest in and knowledge of the Celts? For this purpose, we look at the additional questions asked in both questionnaires. In each questionnaire, the players were asked how confident they were in their own answers on the subject of the Celts. The answer was given in each case by a scale from not-at-all <1> to very <7> confident.

In group M, confidence regarding their own answers in the knowledge questions increased from 1.75 (SD=1.06) to 4.67 (SD=1.30). Likewise in group S, confidence regarding their own answers in the knowledge questions increased from 1.75 (SD=0.97) to 4.83 (SD=1.11). The increase in contentment with their own answers in the knowledge questions is significant in both groups (Group M: t=2.201, p=2.270E-05; Group S: t=2.201, p=8.538E-07).

We asked the players in both questionnaires to what extent they agree with the statement that they have basic knowledge about the Celts. The answer was given in each case by a a seven-point Likert-scale from strongly disagree <1> to strongly agree <7>. Both groups disagreed with this statement in the pre-test (Group M: 2.58 (SD=1.51); Group S: 2.33 (SD=1.23)). This changed in the post-test. Here, both groups agreed with the statement (Group M: 4.42 (SD=1.73); Group S: 4.33 (SD=1.30)). This change is significant (Group M: t=2.201, p=8.647E-04; Group S: t=2.201, p=0.002).

- **Q2: What impact does the competitive multiplayer mode have compared with a single-player mode on learning motivation and learning outcomes?**

As shown, *Oppidum* was able to transfer knowledge to the players in both groups and consequently in both game modes. To answer the second research question regarding the learning outcome, we now examine the previous results for differences depending on the game mode. The first interesting aspect is the change of the players' knowledge through the game. In this case it is the knowledge gain, which is expressed by the difference of the knowledge scores from pre- and post-test. Group M has gained 26.7% (SD=0.23) and group S 20.0% (SD=0.18). This does not represent a significant difference between the groups (t=2.074, p=0.438).

Both groups were more confident in their answers in the post-test. The score for confidence increased in both groups, but the differences between the two measured scores (Group M: M=2.92, SD=1.44; Group S: M=3.08, SD=1.08), were not significant (t=2.074, p=0.752). Similarly, the data collected on the answers given in the QuizWar or the rune quiz do not show any significance with respect to the groups (t=2.074, p=0.700). The players who played the multiplayer mode answered on average 61.8% (SD=0.09) correctly. In the single-player mode, 59.6% (SD=0.18) did so.

Overall, we did not find a significant difference in the groups in terms of learning outcomes.

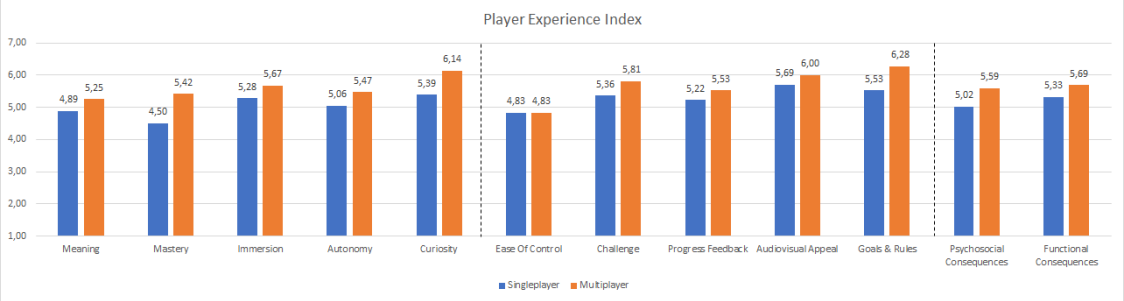


Figure 6.14.: Results of the Player Experience Inventory (PXI) (Gomm, 2020)

Learning Motivation We analyze the players' motivation to get involved with the learning content on the one hand, and the basic intrinsic motivation that emerges from the player experience on the other. Again, we use data measured during the game.

In this case, the number of information panels with learning content that were read and the time that the players spent reading these information panels. Participants in group M engaged with an average of 9.92 (SD=2.58) information panels for an average of 17.2 (SD=8.7) seconds. Group S looked at an average of 6.92 (SD=6.22) information panels with a time spent of 10.8 (SD=10.7) seconds.

Motivation and Player experience Motivation arises from the player experience (see section 2.1). Consequently, we used the PXI (see subsection 6.5.2) questionnaire to examine the player experience in terms of functional and psychosocial consequences.

The evaluation of the PXI (see Figure 6.14) shows that basically all calculated scores in both test groups of the individual constructs are above the expected value of 3.5. Thus, *Oppidum* generates a good player experience and supports the intrinsic motivation of the players.

The values depending on the game mode show the same value for *Ease of Control* (Dynamics). This is explained by the fact that the interactions with the game are the same regardless of the selected mode. However, it is the lowest score of group M for a construct. Handling AR is initially unfamiliar for some players. In addition, the tracking does not work properly, e.g. due to poor lighting.

In all other constructs, the score of players who played the multiplayer mode is higher than that of players who played the single-player mode. But only the score for the construct *Mastery* (Aesthetics) is significantly higher (Group M: M=5.42, SD=1.21; Group S: M=4.50, SD=0.92; t=2.074, p=0.048). The players of group M have more feeling of competence.

As we have already noted, group M also dealt more extensively with the information panels and was thus able to learn more facts about the Celts. Even though the scores of the individual constructs and the knowledge gain are not significantly higher, a tendency can still be observed. The multiplayer mode generated an improved player experience and thus more motivation to learn and to get information. Reichart and Bruegge (2014) had already noted similar effects and pointed out that social interaction in particular is often missing in Serious Games. In the open feedback of the questionnaire, the players especially mentioned the multiplayer mode positively. The multiplayer mode offers another advantage that is not apparent from the questionnaires. Due to the possibility to play with different opponents, players are more motivated to play *Oppidum* more than once, which clearly increases the knowledge transfer.

How was the usage of AR perceived? Since the use of AR is elementary for the game, no other variant without AR was implemented. However, we can get information from the open questions of the questionnaire and from the results of the PXI. AR can be associated with *Curiosity* and *Immersion* (Aesthetics) or *Ease of Control* and *Audiovisual Appea*l (Dynamics). We consider these constructs and their evaluation below:

- *Curiosity* and *Immersion*: These Aesthetics were rated highest in both groups (Curiosity: 5.39 (S); 6.14 (M); Immersion: 5.28 (S), 5.67 (M)). It was already intended

during the planning of the game to trigger the curiosity of the players with the help of AR. Like using a magnifying glass, players can look for information or rune stones in a small 3D environment located right in front of them. The ability to see inside the houses enhances this effect and creates additional immersion, as players can literally immerse themselves in the 3D objects.

- *Ease of Control* and *Audiovisual Appeal*: Both groups gave the identical and at the same time the lowest rating (4.83) for Ease of Control in the Dynamics section. The reason can be found in the use of AR, in addition to other parameters that must be counted as part of this construct. Interaction with markers in AR must first be learned and can be influenced by external circumstances such as lighting. Consequently some participants experienced problems here. Feedback from the open questions confirms this. Furthermore, holding the tablet while scanning or inspecting was also described as uncomfortable and tiring. Audiovisual Appeal is strongly associated with Curiosity and Immersion, so high ratings (5.69 (S), 6.00 (M)) are also given here. If the game world is presented in a visually appealing way (Dynamics), these aesthetics and sensation (Hunicke et al., 2004) can be triggered.

6.6. Summary

In this chapter we presented the Serious-AR-Game *Oppidum*. With the help of AR it is possible to combine the digital game with elements of the classic board game. The construction and management game was designed to contain entertaining and educational elements. The goal was to transfer knowledge about the tangible as well as intangible cultural heritage of the Celts to the player. For this purpose, historically accurate modeled buildings were used, which can be viewed and inspected in 3D with the help of AR. The knowledge gained is tested in the game through the so-called QuizWar. For the game, both a single player and a multiplayer mode were implemented. In a study, we used questionnaires to examine the extent to which *Oppidum* can transfer knowledge about the cultural heritage of the Celts to the player and the influence of the game mode on motivation and knowledge gain. 24 test persons played one game mode each in two groups of equal size. We found that the players in both game modes had a significant knowledge gain. In the comparison of the game modes, the players of the multiplayer mode achieved the higher scores, but no significant difference could be found with the other group.

In their feedback, the players praised the game design and especially the multiplayer mode. Furthermore, some players were surprised how much they had learned subconsciously through the game and suggested to transfer the game concept to other cultures. We gladly followed this suggestion and are currently working on a game called *LegionARius*, which deals in a similar way with the cultural confrontation of Romans and Germanic tribes at the Limes.

In summary, *Oppidum* was successful in imparting knowledge to players. The multi-player mode almost consistently delivered higher scores than the single-player mode in both knowledge gain and player experience.

7. HieroQuest

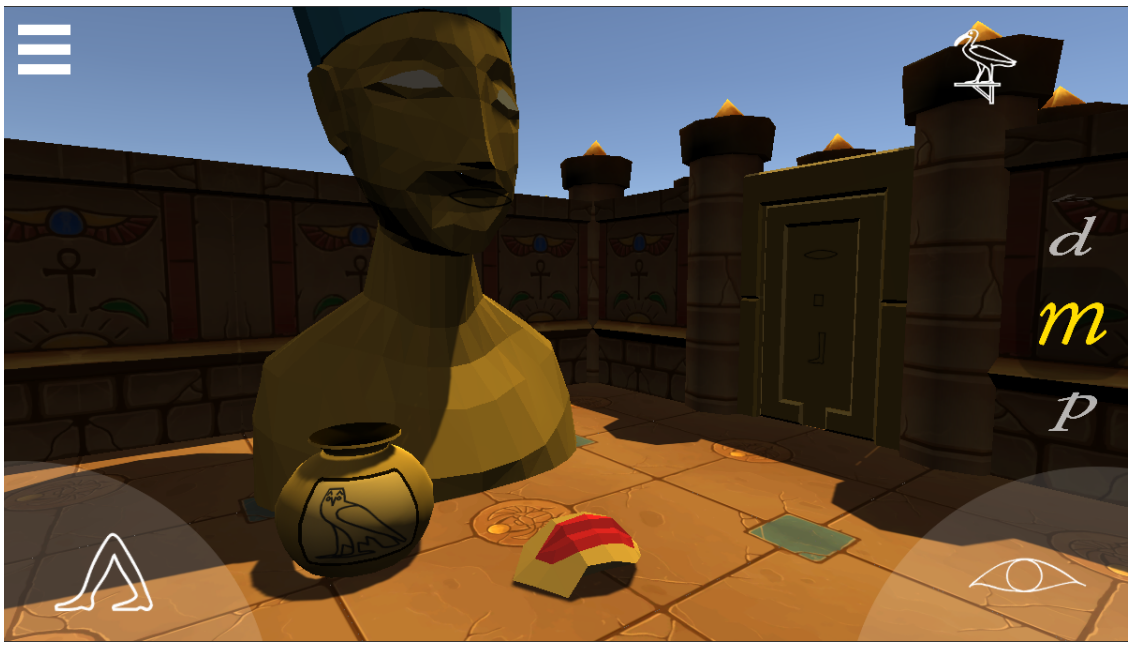


Figure 7.1.: *HieroQuest* (Plecher et al., 2020)

This chapter introduces the Serious Game *HieroQuest* and its development. The idea to design a Serious Game about hieroglyphs was born during the visit of an exhibition about the tomb of Tutankhamun. Hieroglyphs are often perceived as something mysterious. Most people know that they are the characters of the ancient Egyptians, but only few people are actually able to read them. This project was only possible in cooperation with students and with the support of experts. The basic idea and the first prototype was developed together with Daniel Fedh (Fedh, 2017) and Dennis Nehrenheim (Nehrenheim, 2017). The further development and the main study were carried out together with Florian Herber (Herber, 2018) under the expert advice of Dr. Alexander Schütze from the Egyptology Department of the Ludwig-Maximilians-University, Munich. The description of the game including the different iterations and the results of the main study have been published as an article for the *Journal on Computing and Cultural Heritage (JOCCH)* (Plecher et al., 2020).

Our goal was to create a Serious Game that transfers knowledge about hieroglyphs as part of the intangible Egyptian heritage to the player. Thence, we combined the concept

of an escape game with the learning content. The progress in the game is directly linked to the knowledge gain. During the design process of the proposed game called *HieroQuest*, we investigated the following research questions:

- **Q1: Can a Serious Game transfer knowledge about the Middle Egyptian language?**
- **Q2: What impact does the autonomous use of a game mechanic have on learning success in a Serious Game?**

7.1. Serious Content: Intangible Egyptian Cultural Heritage

HieroQuest deals with different aspects of intangible Egyptian cultural heritage. This is on the one hand the language or the characters (hieroglyphs) and on the other hand the literature (*Story of the Shipwrecked Sailor*).

7.1.1. Hieroglyphs

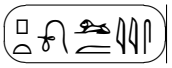
The term hieroglyphs refers to one of the oldest scripts of mankind. It is a combination of the ancient Greek words *ἱερός* (holy) and *γλυφή* (carving) and means sacred writing or holy signs. In the time of the pharaohs, the Egyptians also called them the "Words of God". It was used approximately from 3000 BC to 500 AD. Within this period the development of the Egyptian language can be divided into three periods: Old Egyptian (2700-2200 BC), Middle Egyptian (2200-1350 BC) and Late Egyptian (1350 BC - 3rd century AD). During these processes the language became more structured and the hieroglyphs also developed further. (Höveler-Müller, 2014)

For a long time, their appearance has falsely given the impression of having only a pictographic meaning. But there is much more to it than that. Over time, hieroglyphs have evolved and can be classified into three different categories: phonograms, logographs and determinatives (Jenni, 2013). The distinction between phonograms and logographs can be explained with the 'Senet'. This game was not only put into the grave with Tutankhamun, it has also its own hieroglyph:  . In combination with a mute vertical stroke which symbolizes logographs it has the meaning of the shown object, the Senet. As a phonogram this hieroglpyh represents a speech sound. In this case it will stand for the Latin letters 'mn'. The sounds strung together result in a new word, which again has nothing to do with the objects depicted. This phenomenon, which has made the decoding of the hieroglyphs rather difficult, is called *Rebus Principle*. The third possible use of hieroglyphs are determinatives. Here the hieroglyph is placed at the end of a word to specify its meaning. This is especially reasonable if a word can be used differently with multiple connotations (Ziegler, 2002). At this point it must be mentioned that the reading direction of hieroglyphs is flexible. The depicted animals or humans always look at the beginning of the sentence

25 uniliterals were used in the Middle Egyptian language. Each represents as a phonogram a single literal. For example, means 'd'. Almost every letter of the Latin

alphabet can be mapped in this way. We used this as a basis for the first prototype. However, the Middle Egyptian language also offers the use of multilitteral hieroglyphs. As already shown for the Senet - equals 'mn' - each sign stands for two or more letters. 736 of these multiliterals were classified in 26 categories in the famous list named after its inventor A. H. Gardiner (Gardiner, 1957).

The knowledge about the meaning of hieroglyphs was lost around the 5th or 6th century AD. It took more than a thousand years until a unique archaeological find made the decoding possible. The so-called 'Rosetta Stone' was discovered during the Napoleonic campaign in Egypt in 1799. The peculiarity of this stone is that it contains one and the same inscription - a decree of Pharaoh Ptolemy V - in hieroglyphics as well as in demotic and ancient Greek, so that it could be read by all parts of the population. Although the content of the text was thus known, it was not until 1822 that Jean-François Champollion succeeded in deciphering the hieroglyphs. The decisive clue were the cartouches, which mark the name of the pharaoh. In this case the following cartouches were the key:

- Pharaoh Ptolemy ('ptolmys'): 
- Cleopatra ('kliopadra'): 

After deciphering the cartouch of pharaoh Ptolemy on the Rosetta Stone, Champollion was also able to discover the name of Cleopatra in an inscription on the 'Philae obelisk'. Another special aspect helped him with the translation. Both names have no Egyptian origin. Since the conquest of Alexander the Great in 332/331 BC, the rulers of Egypt were descendants of the Macedonians. More precisely, descendants of Ptolemy, a general of Alexander. Since this is a translation of an actually Greek name in hieroglyphs, simple single-literals were used to reproduce the sound.

7.1.2. The Story of the Shipwrecked Sailor

As mentioned above, there is a variety of multiliterals. Therefore, the idea was born to enhance *HieroQuest* according to the requirements and the curriculum of the first semester of the Egyptology studies at the LMU. After the introductory phase, the students there deal with one of the oldest stories of mankind. *The Story of the Shipwrecked Sailor* is completely preserved on a papyrus that is believed to date back to the Twelfth Dynasty (1991-1802 BC). This papyrus belongs to the collection of the Imperial Museum in St. Petersburg. (Burkard, Thissen, & Quack, 2003, p.148) The story is written in *hieratic*, a cursive variant of the hieroglyphic script, and was later transferred to hieroglyphs (e.g. (Blackman, 1932, p.41-48)). The text transmits the story in the form of a conversation between a captain of a failed expedition and his attendant. The latter tries to calm the captain, who is now afraid of the consequences, with his own story. The attendant had not succeeded in bringing the crew home, as the ship had sunk in a storm. He was the only survivor and could save himself on an island. There he meets a talking

snake, which rules over the island. The snake does not threaten him, instead it gives him presents and helps him to leave the island and return home.

According to the text, a single scribe wrote it on the papyrus: *"Here endeth [The Story of the Shipwrecked Sailor], which hath been written from the beginning to the end thereof according to the text that hath been found written in an [ancient] book. It hath been written*[1] *by Ameni-Amen-āa, a scribe with skillful fingers"* (Wallis Budge, 2005).

7.2. Related Work

In this section related work is considered, which also dealt with the cultural heritage of the Egyptians. In order to structure them, the taxonomy of Mortara et al. (Mortara et al., 2014) for Serious Games and Cultural Heritage was used. In order to get an exact overview, not only Serious Games, but basically Serious Applications focusing on Egyptian cultural heritage were included.

7.2.1. Heritage Awareness

Heritage Awareness means that the games or applications are particularly concerned with an accurate representation or reconstruction of historical buildings. This can be done in the form of images but also with 3D objects.

One example is *Walk like an Egyptian*. The game was implemented in 2015 and is based on a kind of city walk through Cairo, visiting the most important sights. It is designed for tourists but also for locals to motivate them to visit the historical sites. On site the player is provided with pictures and information. On the basis of this information, questions have to be answered afterwards (Gabr & Abdennadher, 2015).

In 2017, Ubisoft released *Assassin's Creed: Origins*[2], which takes the player to the Egypt of Cleopatra's time (about 50 BC). Great importance was attached to the reconstruction of the buildings in order to create an accurate image of the time. The example of the famous Library of Alexandria illustrates one problem in particular. The ancient sources and archaeological findings are often nowhere near enough for reconstructing the building. In this case the library of Celsus in Ephesus was taken as a model. *Origins* is not intended to be a Serious Game, but it does present a historical illustration as accurate as possible. The game is complemented by a so-called *Discovery Tour*, which offers the player guided sightseeing tours with lots of background information. During the tour no enemies can be defeated or quests completed, the focus is only on knowledge transfer. In game mode, the quests have no historical reference. The game takes place against a historical backdrop.

Egyptian culture is of course an important topic in museums. Many cultural assets from Egypt can be found in various museums all over the world. One technique that

[1] The story does not have an author in the usual sense and was simply copied and captured for posterity by the scribe in question.

[2] `https://www.ubisoft.com/de-de/game/assassins-creed-origins` [accessed 2020-06-15]

offers the visitor a completely new experience during the visit is AR. In the *TombSeer* project an AR application of the Tomb of Kitines was created by Pedersen et al. (2017) for the Royal Museum in Ontario. Virtual information about the exhibits is displayed to the visitor. Additionally it is possible to interact with virtual exhibits.

Virtual Reality (VR) is also used to present Egyptian tangible cultural heritage. Jacobson et al. (2005) were one of the first to build a virtual Egyptian temple in 3D. This was not a virtual replica of a still existing or destroyed temple. The focus was to show all building elements of a certain time epoch, in this case the New Kingdom, on one single model. "This way, it clearly and cleanly supports educational narratives which increase early understanding of Egyptian culture" (Troche & Jacobson, 2010).

The tomb of Nefertari in the Valley of the Queens in Egypt, however, served as a real archetype for several VR projects. Nefertari was the first of the Great Royal Wives of Ramesses the Great. Already in 1998 the Canadian Museum of Civilization offered its visitors virtual but not interactive tours through her tomb in a Virtual Reality 3D Theatre as part of the exhibition “Mysteries of Egypt” (J. Taylor, Boulanger, & Rioux, 1999). A fairly recent example is created by the ExperiusVR developer team. They used 3D scanning technology and a plethora of DSLR pictures for photogrammetry to reconstruct a nearly perfect 3D model of the tomb. The project is called *Nefertari: Journey to Eternity*[3] and can be downloaded for free to start the location-independent visit using an VR headset. In contrast to the original excavation site, the visitor can explore the entire tomb. The user has the possibility highlight parts of the painting on the wall with a virtual flashlight and gets informed by an audio-guide.

7.2.2. Historical Reconstruction

Egypt 1156 BC Tomb of the pharaoh (released by Cryo in 1997) is an "Ancestor of current Serious Games" (Djaouti, Alvarez, Jessel, & Rampnoux, 2011) that tries to reconstruct a specific historical event. In a part of the adventure game the player explores the tomb of Seti I and experiences the process of an Egyptian funeral. The strategy game *Egypt: Old Kingdom*[4] by Clarus Victoria is another example of that kind. Egyptologists were involved in the development process to create a historically accurate gaming environment. The player can witness the historical founding process (3500 BC - 2410 BC) of the Old Kingdom in Memphis. The game is round based and presents the player with the task of developing his tribe in order to found the first empire by unifying with other tribes.

7.2.3. Cultural Awareness

Games or applications like *HieroQuest*, that deal with the intangible cultural heritage of the Egyptians should be presented here. We only could identify more or less serious

[3] `https://www.oculus.com/experiences/rift/1491802884282318/` [accessed 2020-06-15]
[4] `https://store.steampowered.com/app/646500/Egypt_Old_Kingdom` [accessed 2020-06-15]

applications focusing on hieroglyphs. *Hieroglyphic Writer*[5] is an app for Android devices, which translates a text provided by the user into hieroglyphs. However, no words are translated into hieroglyphs or Middle Egyptian. It is only a letter by letter transfer from Latin characters to hieroglyphs. This way the user can write his own name in an ancient writing system or at least practice the simple single-literals. *Hieroglyph Flash Cards*[6] is also an app for smartphones, but can be used as a real learning tool for Egyptology students. It includes a dictionary and a vocabulary training program for single- and multi-literals. In addition, various exercises are offered, such as deciphering inscriptions or cartouches.

After looking at the related work, it can be said that there are no Serious Games that are actually designed to bring Egyptian intangible cultural heritage closer to the player.

7.3. Game Design

A good Serious Game does not only connect the worlds of gaming and learning, so that they coexist with a certain interface, but lets these worlds merge. The game world should get an Egyptian look in this case. A great advantage from a design point of view is the fact that hieroglyphs also have a logographic meaning. The representation of the corresponding object not only enriches the game world, but also helps the player to remember its meaning. This ensures the fusion of learning content and game design. The retrieval of what has been learned is an important factor in actually acquiring knowledge and storing the information in the brain. Furthermore, it is always a problem to integrate this query into the game in a meaningful way. Quiz questions are often built in for this purpose without any apparent reason - from the player's point of view. The solution for *HieroQuest*, which is designed as a puzzle game, is thematically borrowed from Egyptian mythology. The 'Book of the Dead' says that on the way to the underworld, the deceased must pass through several gates secured by guards to test whether he is worthy of entering. Only by mentioning the names of the guards they are granted passage (Assmann, 2003; J. H. Taylor, 2010). We have integrated this into the game as follows: The player finds himself in an unspecified Egyptian temple and has to escape from it. The exit can only be reached by walking through different rooms and also different gates. The gates are marked with hieroglyphs (see Figure 7.3, annot. 1), which the player has already learned in the progress of the game or encounters in the current room. The hieroglyphs guard the gate, so to speak, hence the gate can be opened by mentioning its meaning respectively its transliteration.

The game was implemented with Unity3D [7] and designed for smartphones and tablets. The environment of the game is shown to the player from the ego perspective of the character to be played. It is controlled with two virtual joysticks, which appear because

[5] `https://play.google.com/store/apps/details?id=com.civilizationguards.hieroglyphicwriter`[accessed 2020-06-15]

[6] `https://play.google.com/store/apps/details?id=es.doneill.android.hieroglyph.flashcards`[accessed 2020-06-15]

[7] `https://unity.com` [accessed 2021-02-01]

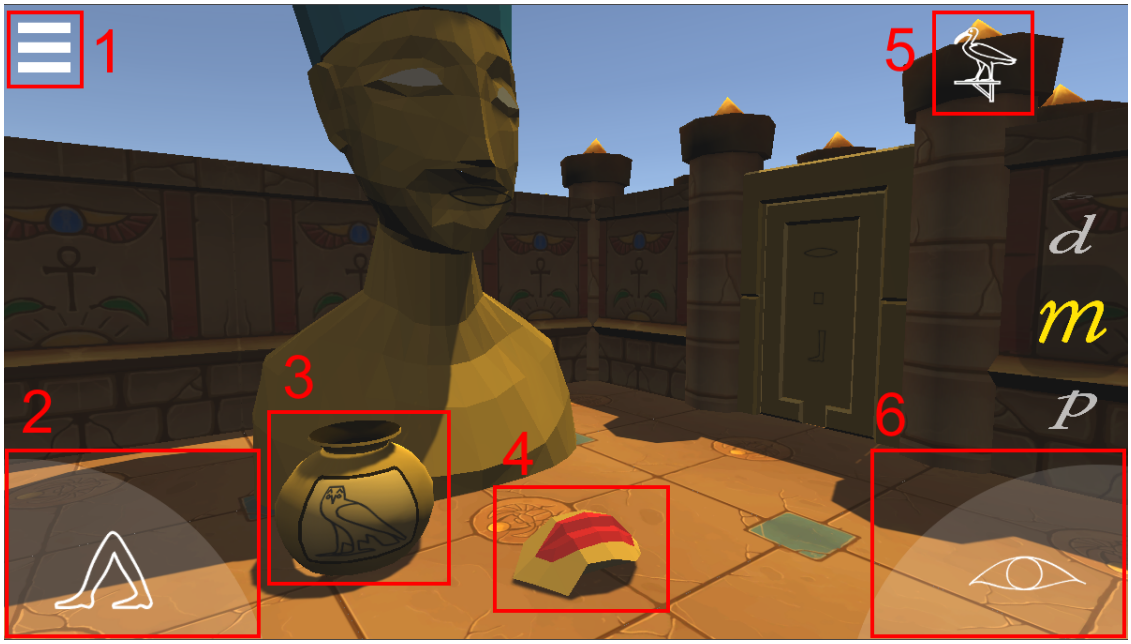


Figure 7.2.: User Interface: (1) Menu, (2) Virtual Joystick: Movement, (3) Breakable Vase, (4) Object: Mouth = r (), (5) Hint System: Toth, (6) Virtual Joystick: Gaze (Plecher et al., 2020)

of the touch-sensitive display as soon as the player puts his thumbs on the hieroglyphs in both lower corners. The hieroglyphs refer to the actions that can be performed with it. The logographical meaning of (D54) (see Figure 7.2, annot. 2) is "to go" and therefore this joystick is used to move the character in any direction. The camera and consequently the direction of the character's gaze is controlled with (D5) (see Figure 7.2, annot. 6) in the lower right corner, which used as determinative stands for "to see".

7.3.1. Serious Game Mechanics

In the following, we introduce the most important elements of the game individually and present their importance both for game play and for conveying information. A detailed explanation of these follows in the individual descriptions of the iterations of the development process. For classification, we use the LM-GM model (Arnab et al., 2015) in combination with the MDA framework (Hunicke et al., 2004). A summary of the mechanics, the respective implementations and the triggered aesthetics is shown in Table 6.1.

Rooms: The game is structured by individual rooms *(GM: Levels)*, in which hieroglyphs can be discovered. Furthermore, this also organizes the learning process and guides the player through the learning content *(LM: Guidance)*. Reaching a new room is on the one hand the reward for mastering the previous room and on the other hand offers

HieroQuest			
Game Mechanic	**Learning Mechanic**	**Implementation**	**Aesthetics**
Levels	Guidance	Rooms	Discovery, Mastery
Story	Motivation	Story of the Shipwrecked Sailor	Narrative
Minigames	Repetition, Reflection, Analysis	Unlocking Hieroglyphs	Mastery
Questions & Answers	Feedback, Repetition	Usage of Hieroglyphs	Mastery

Table 7.1.: LM-GM Analysis of *HieroQuest* according to Arnab et al. (2015) augmented with aesthetics from the MDA Model (Hunicke et al., 2004)

the possibility to discover new information. This triggers the Aesthetics *Mastery* and *Discovery*.

Story: In contrast to *DragonTale*, in this case the story of the character is not in the focus. Instead, the player gets to know *"The Story of the Shipwrecked Sailor"* indirectly, piece by piece, and is thus motivated to continue playing or learning *(LM: Motivation)*. This can be associated with the Aesthetics *Narrative*.

Minigames: The game contains a lot of different minigames to present the player with new hieroglyphs or to test already learned knowledge *(LM: Repetition, Reflection)*. If the player is successful, the sense of competence is derived from it (Aesthetics *Mastery*).

Usage of Hieroglyphs: In most cases, the player uses the hieroglyphs to open the doors. This door riddle represents the *Game Mechanic Question&Answer*. The hieroglyph on the door symbolizes the question, which is answered by selecting the correct transliteration. The player receives direct *Feedback (LM)*. In this way, the learning content can be tested and repeated *(LM: Repetition)*. The successful opening of the door triggers the Aesthetics *Mastery*.

7.3.2. First Iteration

HieroQuest was developed in several iterations. Table 7.4 summarizes the corresponding implementations, questions and studies. The first version deals with the unilateral hieroglyphs. In the already mentioned temple structure the hieroglyphs can be unlocked by solving small puzzles or mini-games. The corresponding transliterations are then added to the Literal Picker (see Figure 7.3, annot. 2). The player uses that tool to interact with objects marked with a hieroglyph. For example, to open the door (see Figure 7.3, annot. 1) it is necessary to first select the appropriate transliteration in the

Figure 7.3.: The game is structured by rooms that can only be entered by solving the riddles on the door (Plecher et al., 2020)

Literal Picker and then to click on the corresponding hieroglyph. Figure 7.3 shows an example for the correct procedure, because transliteration *r* was selected and afterwards the hieroglyph 𓂋 was clicked. The same procedure is used to break vases (see Figure 7.2, annot. 3) marked with a hieroglyph or to pick up certain objects (see Figure 7.2, annot. 4). In this way, checking the learning content is ensured and repetition helps to remember it.

7.3.2.1. Basic Gaming Elements

Different types of puzzles were integrated to create a variety of ways to unlock the hieroglyphs. One of them is the so-called "Pick Up"-riddle. Basically, this is all about picking up and placing objects in the right location. This sort of riddle was used when the logographic meaning of the hieroglyph could be represented by an object. An example can be seen in Figure 7.2. The mouth 𓂋 (annot. 4), which represents the r, must be picked up and inserted into the statue. We use similar puzzles for the letters a (𓄿),b (𓃀) and d (𓂝), which also represent body parts. In this way the gaming and learning world can be connected. For hieroglyphs whose meaning cannot be represented so easily by objects, a more dynamic puzzle type was developed. This is based on tiles, which have to be collected and inserted into a mural. In a more difficult version, the "Slide Riddle", the tiles on the wall have to be moved into their correct position first (see Figure 7.5). Only one tile at a time can be moved to a free adjacent field. When this has been done correctly, the tile can be inserted in the place provided. Another type of puzzle is called "World Highlight". It uses the logographic meaning for the

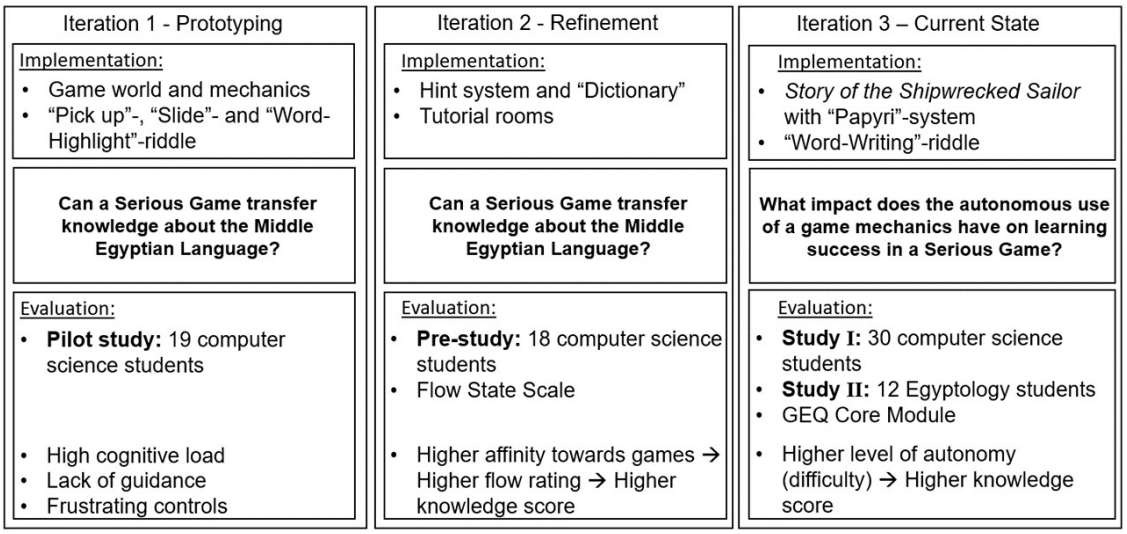


Figure 7.4.: Overview of research foci, improvements and user studies for each iteration (Plecher et al., 2020)

representation by objects. Here, no tiles or objects are moved, but they can be observed from certain angles. This can be explained best by the example of the hieroglyph p (□). It shows a square, which represents a cube-shaped stool. For the learner it is not so easy to associate a simple square with a stool. In this type of puzzle it shall be shown, how this association was created by the Egyptians. The viewing angle is an important factor. It is now the player's task to look at such a stool from different angles, until the seat can be seen as a planar square. Before the correct orientation is achieved, a black border in the form of the hieroglyph appears first, which turns yellow at the end (see Figure 7.6, annot. 1-4).

Figure 7.5.: "Pick Up"- and "Slide"-riddle (Herber, 2020)

Figure 7.6.: Different stages of the "World Highlight"-riddle for p (□) with different angles: (1) No detection, (2,3) Stool is marked, (4) Unlocking p (□) (Plecher et al., 2020)

7.3.2.2. Small Evaluation of the first iteration

To test this early version of the game, a small study was conducted.The participants were students of the computer science department at TUM, who of course had experience with games, but no prior knowledge of hieroglyphs or Middle Egyptian. The number of participants was 19 (14 male, 5 female) and was spread over the age group 21 to 35 (M = 26). The playing time was 40 minutes and questionnaires were distributed afterwards. The questions related to both the evaluation of the playful elements and the transfer of knowledge. The most important results were:

The test persons liked the idea of getting to know hieroglyphs in a playful way and combining this with a kind of escape room. Furthermore, the evaluation showed that the players better remembered a hieroglyph if its meaning was presented as a 3D object and was hence better or more credibly integrated into the game world. Consequently the stool (□=p) and the mouth ( =r) were almost always correctly assigned in contrast to hieroglyphics like the owl ( =m), which was only presented as a generic tile puzzle.

The study also revealed further potential for improvement. A basic finding was that the players got lost or felt lost due to several problems. Without a tutorial it was not easy even for the experienced test persons to understand all game mechanics immediately. With increasing number of unlocked hieroglyphs it became of course more difficult to

keep them in mind. Since there was no possibility to look up the meanings again, some doors were opened by simply trying. This certainly does not promote the transfer of knowledge. Instead the frustration increases through excessive demand. This overload in playful and cognitive areas led to overwhelming situations. Consequently, the affected players were no longer in flow (see section 2.2.4). It was the task of the second iteration to solve the mentioned limitations.

7.3.3. Second Iteration

In the second iteration the game *HieroQuest* was further developed and improved based on the feedback.

7.3.3.1. Changes and new Gaming Elements

In a Serious Game, it is important not to overwhelm the player either by overly demanding controls or by testing the learned knowledge, e.g. puzzles. In order to guarantee that the players stay in flow (see section 2.2.4), they have to be able to solve the gameplay challenges and learning tasks at any time. Therefore, the following improvements have been introduced.

The first three rooms have been turned into a tutorial to help the player get used to the game mechanics. In contrast to the actual game, text is used for explanation. The focus of the tutorial is not to immerse, but to prepare the player for the further game. By overtaxing the player with the new knowledge the player will abandon the game and consequently the knowledge transfer. In order to prevent the players from feeling lost again if they do not know what to do, the so-called 'Hint System' was introduced. The symbol (see Figure 7.2, annot. 5) of the god Toth, the inventor of the hieroglyphs, is displayed when the player has performed several wrong actions or does not move for some time. When this symbol is clicked, a hint is displayed (see Figure 7.7). The hints refer to the next task that needs to be solved. In order not to underchallenge the player, step-by-step help is offered instead of direct solutions.

A problem of the previous version was that the players could not remember the meaning of all hieroglyphs and there was no way to look them up. Therefore the lexicon was added, which contains all already unlocked hieroglyphs and their transliteration. This can be opened at any time via the menu (see Figure 7.2, annot. 1).

The effects of these changes on the game experience and knowledge acquisition were investigated by another user study.

7.3.3.2. Second Iteration: User study

18 students (13 male, 5 female) in the age range of 21 to 29 (M=24.67, SD=2.16) from the computer science department of TUM participated in this study. They played the new version of the game and filled out a questionnaire with questions about their personal gaming experience and learning content. Furthermore, they were asked about their

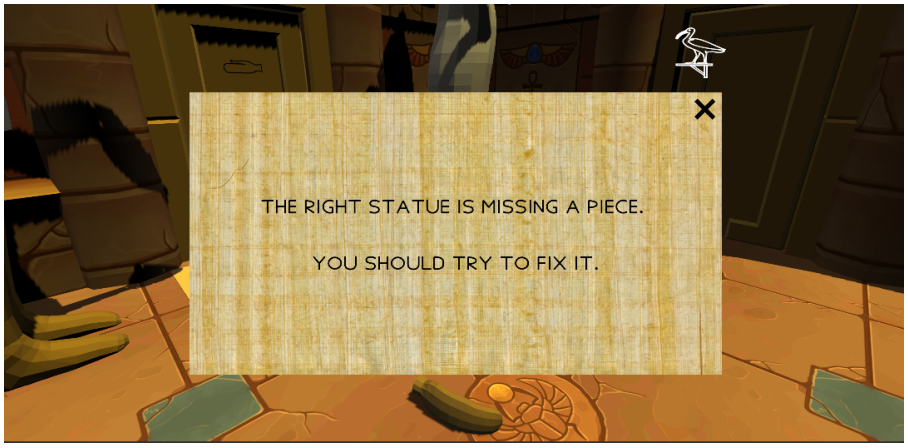


Figure 7.7.: The 'Hint System' offers step-by-step help (Plecher et al., 2020)

previous knowledge of games in general and hieroglyphs in particular. All of them stated that they had no prior knowledge of hieroglyphs. The time they spend playing games per week was reported to be between 0 and 1000 minutes (M=301,58; SD=347.67). To explore the personal experience 27 questions were asked based on the Flow State Scale according to Susan A. Jackson (Jackson & Marsh, 1996). The assessment was based on a Likert scale from 1 to 5. In addition, various questions were asked about the 25 hieroglyphs taught in the game. Either the transliteration of a hieroglyph had to be specified or vice versa. Also multiple-choice and open-end questions were asked.

Between 39% and 93% of the hieroglyphs were recognized and correctly assigned to their transliterations. The results showed that *HieroQuest* is able to convey knowledge about hieroglyphs to the player. This answers the research question asked at the beginning of the chapter. However, it is necessary to take a closer look at the large variation in the data to discover possible correlations. For this purpose, the data was sorted by playing time per week. This resulted in two equally large groups of 9 people each. Group A included the participants who played more than 60 minutes per week. Group B contained those with less playing time per week. Group A achieved a significantly higher ($t(16) = -4.93$, $p = 0.00007$ (one-tailed)) knowledge value (M=0.873; SD=0.066; n=9) than group B (M=0.64; SD=0.116; n=9). The Pearson correlation factor between knowledge score and digital playtime was 0.60. In a further study we created groups in terms of flow rating. 9 people had a score above and below 3.5. It was found that the group with a higher flow rating also had a higher knowledge score (M = 0.849; SD = 0.082; n=9) than the other group (M=0.664; SD=0.146; n=9). This difference was also significant ($t(16) = -3.116$, $p = 0.0033$ (one-tailed)). The Pearson correlation factor between knowledge score and flow rating was 0.43.

Therefore, it can be assumed that experience in dealing with games and a high flow rating have a positive influence on knowledge transfer. If we look at the groups that have the higher values in both categories, we find that they overlap by 78%. Therefore, the greater affinity to games is probably correlated with higher flow rating (r=0.53).

A low level of playing experience is also reflected in a low level of knowledge acquisition. A possible explanation is the excessive demand due to the simultaneous challenge in the playing and learning world. Inexperienced players are more challenged by the unknown game mechanics and therefore cannot focus on the learning content. A Serious Game should be playable by as many players as possible, regardless of their prior knowledge and skills. Therefore, in the third iteration, further improvements were integrated according to the rules of the flow model.

7.3.4. Third Iteration

The third iteration adds new learning elements and the existing game elements are improved as well. Intangible cultural heritage includes not only the language, but also the literature that results from it. *"The story of the Shipwrecked Sailor"* is not only an important cultural heritage in itself, but serves as an introduction to Egyptian literature for students of Egyptology. Hence, the goal was to add this story, but also the related vocabulary to the game. In this way, 40 new words, which are necessary for understanding the story, were added to the 25 uniliterals, which still form the basis of the introduction. The game is played as follows: The player first learns the 25 uniliterals as in the previous iterations and then get in touch with the more complex vocabulary and multiliterals. In addition, papyri were laid out in the new rooms, which tell the player the story step by step. This should further immerse and motivate the player to progress in the game and thus also in the learning process to learn more about the content of the ancient text. Additionally, the papyri illustrate important vocabulary and also teach simple grammar.

7.3.4.1. Game Elements of the Third Iteration

The vocabulary used for the "Story of the Shipwrecked Sailor" often consists of several hieroglyphs. Therefore, it was necessary to invent a new game element to integrate them. The so-called "Word Writing" process is based on the mentioned tile puzzle. The player picks up tiles with the corresponding hieroglyphs and builds the requested word. If this is successfully completed, the word is added to the 'Literal Picker' and can of course be looked up in the dictionary at any time. The example of the word for storm shows this very well (see Figure 7.8). As before, we tried to integrate the meaning of the word into the room, if possible. Therefore it starts to rain after passing through the door. The player collects the four necessary tiles one after the other and puts the word for storm together (see Figure 7.8, annot. 1). In addition, one of the 21 new scrolls (see Figure 7.8, annot. 2) can be collected here. This is part of the 'Papyri system'. The papyrus continues the story and, brings it into connection with the new words supported by pictograms. Figure 7.9 (left) shows such a papyrus. In this case a short text from the story is presented, with the new words (Gale, Storm) highlighted in red. In addition, the words are shown in their transliteration and as a pictogram to support the learning process. In the same way, grammatical phenomena are simply explained. Since

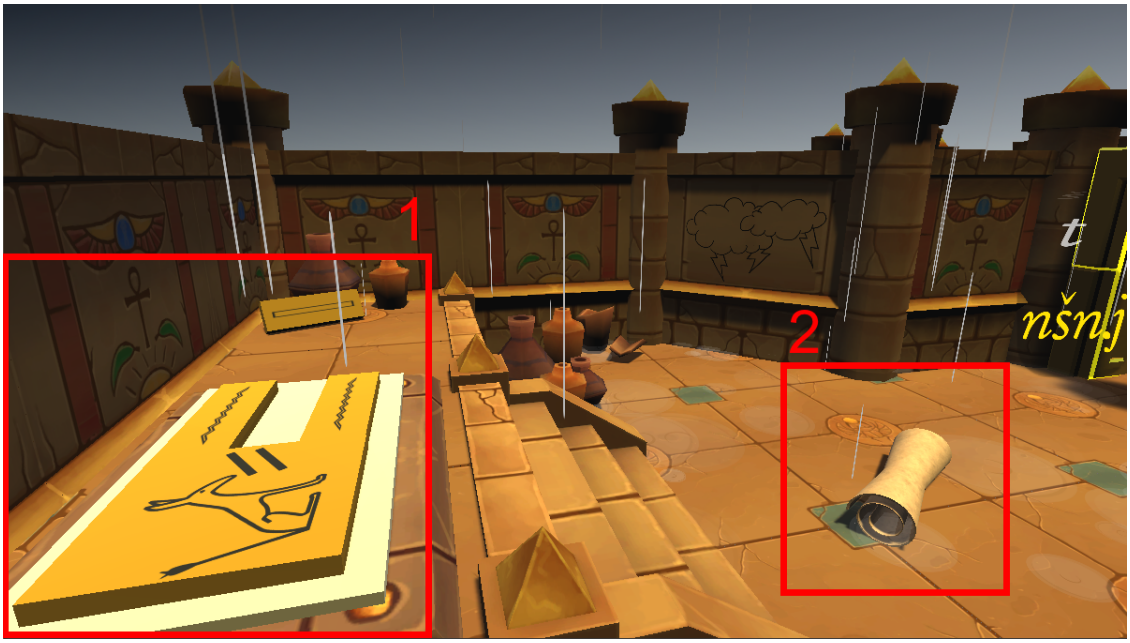


Figure 7.8.: (1) "Word Writing" process: Arrangement of the discovered tiles in the correct order; (2) Papyrus scroll (Plecher et al., 2020)

these are difficult to explain in the form of objects in space, text can be integrated into the game through the papyrus without appearing implausible and without breaking the immersion. The papyrus in Figure 7.9 (right) explains a simple expression of the genitive.

To improve and diversify, new puzzle types were added. A scale and a seesaw serve to convey numbers. Furthermore a memory puzzle was integrated. In summary, the gaming time doubled due to the addition of the new game and learning elements. Since this would go beyond the scope of a study, a reduced level was created for evaluation. This contained a selection of the most important single- and multi-literals, the new words and the papyri that contain the story. This level was the basis for the following main user study.

7.4. Main User Study

After *HieroQuest* was continuously improved and expanded through the various iterations, a larger study could be conducted. For the first time Egyptology students were directly involved. This main study is divided into two parts, which we called Study I and Study II. Study I was mainly attended by students of natural sciences (TUM), who had experience in games, but no prior knowledge of hieroglyphs and Middle Egyptian. Diametrically opposed to this were the participants of Study II Egyptology students of the first semester at the LMU, who of course had previous knowledge on their field of

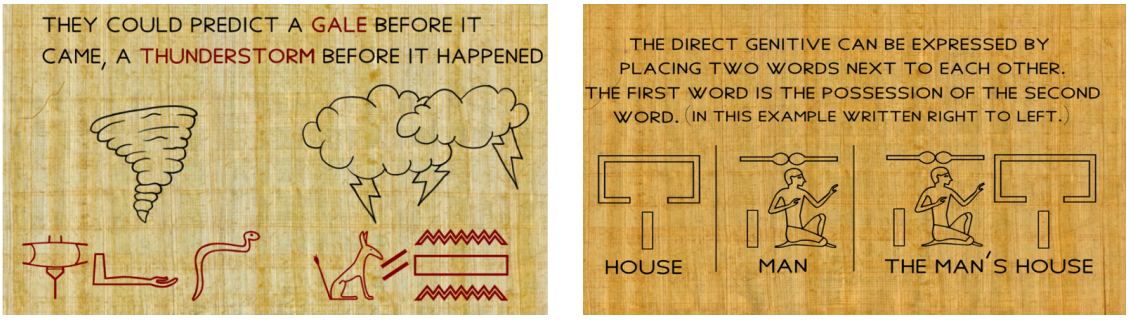


Figure 7.9.: "Papyri"-system: (left) story papyrus; (right) grammar papyrus. (Plecher et al., 2020)

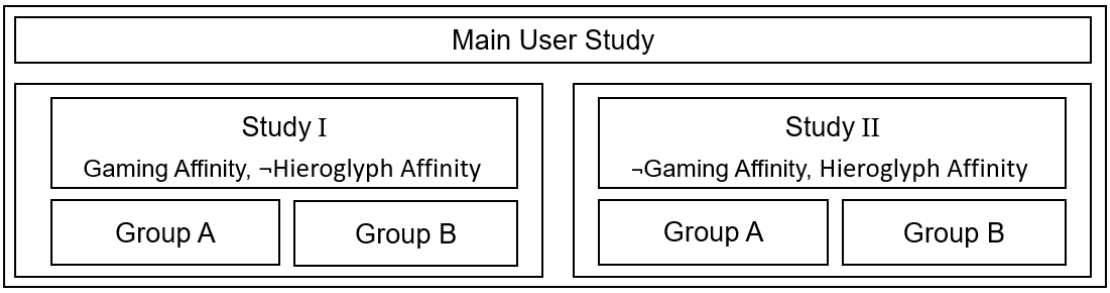


Figure 7.10.: Main user study explanation with Study I and Study II. A and B represent the different versions of the game (Plecher et al., 2020)

study, but had little or no gaming experience. In this way, we were able to examine the two basic components of a Serious Game more closely with two separate studies, each of which included experts from the world of learning or gaming.

7.4.1. Methodology and Procedure

The main study investigates on the influence of the autonomy of the player.
Autonomy is an essential component of SDT (see section 2.2.3) and directly affects the player experience. Previous studies for learning in schools have already shown that an increase in the learner's autonomy leads to an improvement of the learner's performance (Jang, Reeve, & Deci, 2010; Niemiec & Ryan, 2009; Roth, Assor, Kanat-Maymon, & Kaplan, 2007). In order to check whether this phenomenon can also be detected in *HieroQuest*, two only slightly different versions of the evaluation level were created. Versions A and B differ in only one single game element, which gives more autonomy to the players of version B. This experimental setup is based on the research results of Wilson et al. (2009).

Figure 7.11.: Permanently visible hieroglyph hint versus autonomous feature use. (Plecher et al., 2020)

7.4.1.1. Different levels of autonomy.

The term autonomy, consisting of the ancient Greek words *αὐτός* (self) and *νόμος* (law), describes independence or freedom of action. What is the difference between the levels of autonomy in the versions A and B for the player in *HieroQuest*? A main part of the game is the assignment of the transliteration to the respective hieroglyph. For example, the corresponding transliteration is selected from the 'Literal Picker' (see Figure 7.11, annot. 4) to open the doors (see Figure 7.11, annot. 2). In version A, an element has been integrated in the upper right corner (see Figure 7.11, annot. 3) of the screen, which permanently presents the corresponding hieroglyph for the selected transliteration. Version B did not contain this hint, so the player could decide to open the dictionary via the menu (see Figure 7.11, annot. 1) on his own if he was unsure about the answer. This prediction, which directly reveals the solution sought, is the only difference between the two versions.

7.4.1.2. Description of the Evaluation Level

By adding the Story of the Shipwrecked Sailor and the corresponding vocabulary, the game duration increased to about four hours. Also, the 25 single-literals and 40 words were too extensive to learn in one game session. To enable the evaluation of the game, a special level was created. This contains only 13 words, 14 single-literals and 10 papyri, which still covers the whole story. This way, the playing time was reduced to about 90 minutes. This prevents the test participants from being overwhelmed by the duration of the game or the amount of learning content.

7.4.1.3. General Procedure

The test persons were provided a tablet. Where on they played the special level for 90 minutes. In the group of the computer science students (study I) it was ensured by inquiry that none of the participants had previous knowledge of hieroglyphics or Middle Egyptian. For the students of Egyptology (study II) a pre-test questionnaire was created to check their level of knowledge regarding Egyptian hieroglyphs. As soon as a test person completed the special level within 90 minutes, the post-game questionnaire was filled out. If the game was not completed within the given time, the game was automatically aborted after 90 minutes. In this case it could happen that parts of the learning content were not familiarized and therefore could not be answered correctly in the questionnaire. These were nevertheless evaluated. The post-game questionnaire consisted of different parts. The Experience Questionaire (GEQ) by IJsselsteijn, de Kort, and Poels (2013) was used as well as a specially created Learning Content Questionaire (LCQ) were used. Additionally, open feedback and demographic questions were asked. The pre- and the post-game questionnaires can be found in the appendix.

7.4.1.4. Questionaires

The GEQ measures the player's experience and feelings during the game. The 33 questions of the Core Module were used. The questions are answered on a Likert scale from not-at-all <0> to extremly <4> on the seven categories: immersion, flow, competence, positive affect, negative affect, tension, and challenge. The scores for each category were computed as the average value of the single items (IJsselsteijn et al., 2013). In order to check the learning content another 27 questions were asked in the so-called LCQ. These questions related to the 13 words and 14 single-literals presented in the special level. There were different types of multiple choice questions with four possible answers. Either the hieroglyph had to be assigned to the transliteration or the transliteration to the hieroglyph. Alternatively the participants had to give the English translation for a given Middle Egyptian word. The question types were mixed so that the participants remained concentrated. The pre-test of study II to determine previous knowledge contained the same questions as the LCQ in different order. Due to the high number of questions and the additional re-sorting of the answers, the bias was kept as low as possible.

7.4.2. Results of User Study I

In study I 30 test persons took part, who had no previous knowledge about hieroglyphs at all. To additionally test the influence of autonomy, two groups (A and B) of 15 persons each were randomly formed. Group A (n=15; male=13; female=2) played the game with the additional hint. The age range in this group was from 20 to 27 years (M=22.73; SD=2.08) and on average these participants played 11.33 hours of computer games per week (SD=9.29).

Group B (n=15; male=11; female=4) played the game without additional help. The participants were between 19 and 27 years old (M=22.53; SD=2.58) and played an average of 11.27 hours of computer games per week (SD=7.63). In the following, we take a look at the different results of study I, sorted according to the research questions:

- **Q1: Can a Serious Game transfer knowledge about the Middle Egyptian language?**

Since the participants of study I did not have any previous knowledge, the knowledge transfer can easily be indicated by the LCG. Group A reached a knowledge score of 61.4% (SD=0.12) and group B reached a knowledge score of 73.3% (SD=0.09) (Figure 7.12). In both groups a clear increase in knowledge could be measured. Therefore we can answer the research question: *HieroQuest* is able to transfer knowledge about hieroglyphs and Middle Egyptian to the player.

- **Q2: What impact does the autonomous use of a game mechanic have on learning success in a Serious Game?**

Both groups have a significant increase in knowledge (Group A 61.4%; Group B 73.3%; t(28)=1.70, p=0.003). However, this differs significantly between the two groups. Group B, which played without additional help and therefore had to access the dictionary on its own, scored significantly better. Therefore, in this case the second research question can be answered as follows: The *autonomous use* of the dictionary had a *significantly positive* effect on the learning success in *HieroQuest*.

Based on this, a further investigation on the differences between groups A and B in terms of GEQ was possible. The GEQ can basically be divided into 4 positive categories *competence (see section 2.2.3), immersion (see section 2.2.1), flow (see section 2.2.4) and positive affect* and 3 negative categories *tension, challenge (see section 2.2.4) and negative affect*. In each category values between 0 and 4 can be achieved based on the results of the Likert Scale. The evaluation of the results shows values greater than 2 for both groups in the positive categories and less than 2 for the negative categories (see Figure 7.13). Therefore, according to the rules of GEQ evaluation, the values can all be considered "strictly positive". Only in the category "competence" a significant difference between the groups can be determined (Group A: 2.07; Group B: 2.59; t(28)=1.70, p=0.044). This is analysed more closely in the following.

Competence and playing experience measured in playing hours per week revealed a negative correlation in group A (r=-0.789). This effect could not be observed in group B (r=0.06). Here, hardly any change is visible in the values for competence with increasing player experience. The difference of these correlations was significant (z=-2.764, p=0.003) (see Figure 7.14 top left). A significant difference (z=-2.661, p=0.004) in correlation can be shown for *positive affect* and *digital gaming per week* (Group A r=-0.797; Group B r=-0.003) (see Figure 7.14 bottom left).

The correlation between *tension* and *digital gaming per week*, indicates a similar difference for the two groups. In group A, we have a correlation between experience with

digital games and the *tension*-rating (r=0.803). For group B this correlation can hardly be detected (r=0.105). This is a significant difference in correlations (z=2.452, p=0.007) (see Figure 7.14 top right). A similar effect could be determined for *digital gaming per week* in correlation with *negative affect* (Group A: r=0.783; Group B: r=0.05). The difference in correlations is again significant (z=2.702, p=0.003) (see Figure 7.14 bottom right).

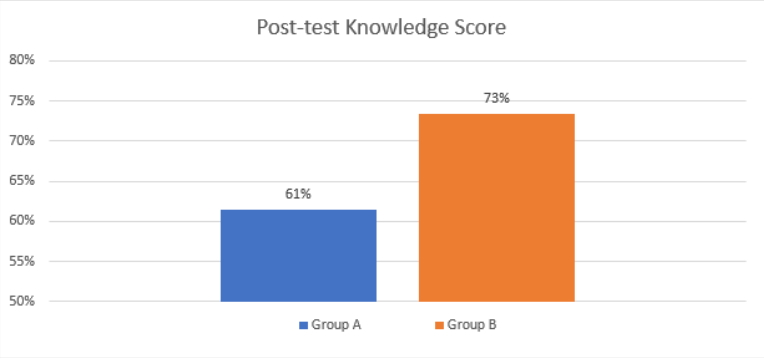


Figure 7.12.: Study I: Knowledge Score of the two groups in the post-test (Plecher et al., 2020)

What do these results and correlations in a synopsis mean? In summary, it can be said that the players in group A were more dissatisfied with more playing time per week. This is shown by the decreasing values of the positive categories as well as the increasing values of the negative categories. Since this effect does not manifest itself in group B, it is due to the permanent vocabulary hint. Serious Games present challenges in both the playful and cognitive areas. Experienced players are already familiar with the game mechanics or at least get used to them very quickly. Therefore, the control and interaction in the game are no challenges for the players. Thus, they can concentrate fully on the learning content. The added vocabulary hint makes the game too easy for the experienced players and the challenge turns into boredom. In group B, the test subjects remained at least cognitively challenged, so there is no correlation and no dissatisfaction. This group also reached the higher knowledge scores, as the participants could decide independently when help and hints were needed. They accepted the challenge and consequently memorized more learning content.

7.4.3. Results of User Study II

12 subjects participated in the user study II. They were Egyptology students and therefore had prior knowledge of hieroglyphs and Middle Egyptian, but had little or no experience in gaming. The previous knowledge was evaluated with a pre-test as described above. Two groups of equal size were formed. The participants of group A (n=6; male=1; female=3; diverse=2) were between 23 and 51 years old (M=30,5; SD=2.3) and played the special level version with permanent vocabulary hint. The average playing time per week of this group was 2 hours (SD=2.31). The participants of group B were between 19

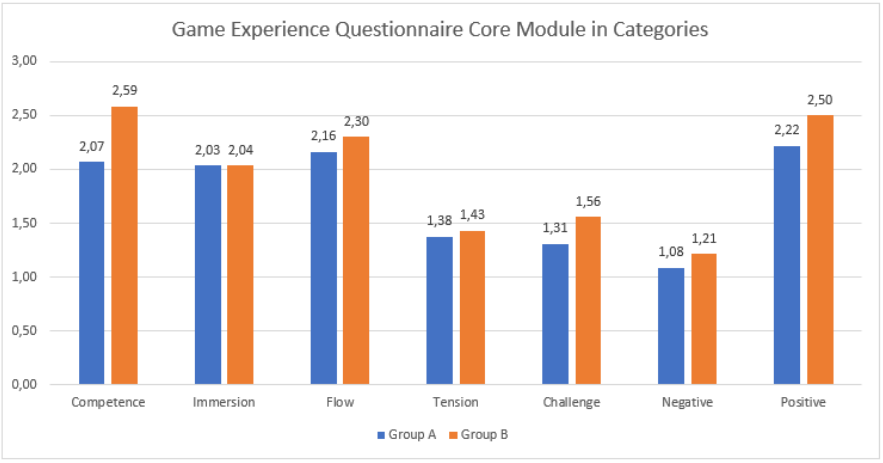


Figure 7.13.: Study I: GEQ Core Module, Average in the different categories for group A and group B (Plecher et al., 2020)

and 35 years old (M=25.5; SD=5,56) and played the version of the special level without permanent vocabulary hint. The average playing time per week of this group was 3.67 hours (SD=3.5). This study shows, besides the main research questions, how *HieroQuest* is accepted by participants with previous knowledge and how it is seen as a learning tool.

- **Q1: Can a Serious Game transfer knowledge about the Middle Egyptian language?**

Group A achieved a knowledge score of 61.7% (SD=0.10) in the pre-test and group B scored 68.5% (SD=0.12). The diagram (see Figure 7.15) shows that both groups could expand their knowledge by playing *HieroQuest*. After evaluating the post-game questionnaire the average knowledge score was 72.2% (SD=0.14) for group A and 77.2% (SD=0.11) for group B. The differences in the results from both questionnaires were significant in each group (Group A: t(6)=2.02, p=0.01; Group B: t(6)=2,015 p=0.004). Therefore, it can be confirmed for study II that *HieroQuest* can transfer knowledge about hieroglyphics and the Middle Egyptian language even if some of the learning content is already known by the player.

- **Q2: What impact does the autonomous use of a game mechanic have on learning success in a Serious Game?**

The average knowledge score gain for group A was 10.5% (SD=0.07) and for Group B 8.64% (SD=0.05). The differences between these values of each group were not significant (t(10)=1.81, p=0.31). Therefore, regarding the research question, we can say that the autonomous use of a game mechanic in study II had no influence on the learning success in *HieroQuest*. This could be explained by the motivation and interest of the

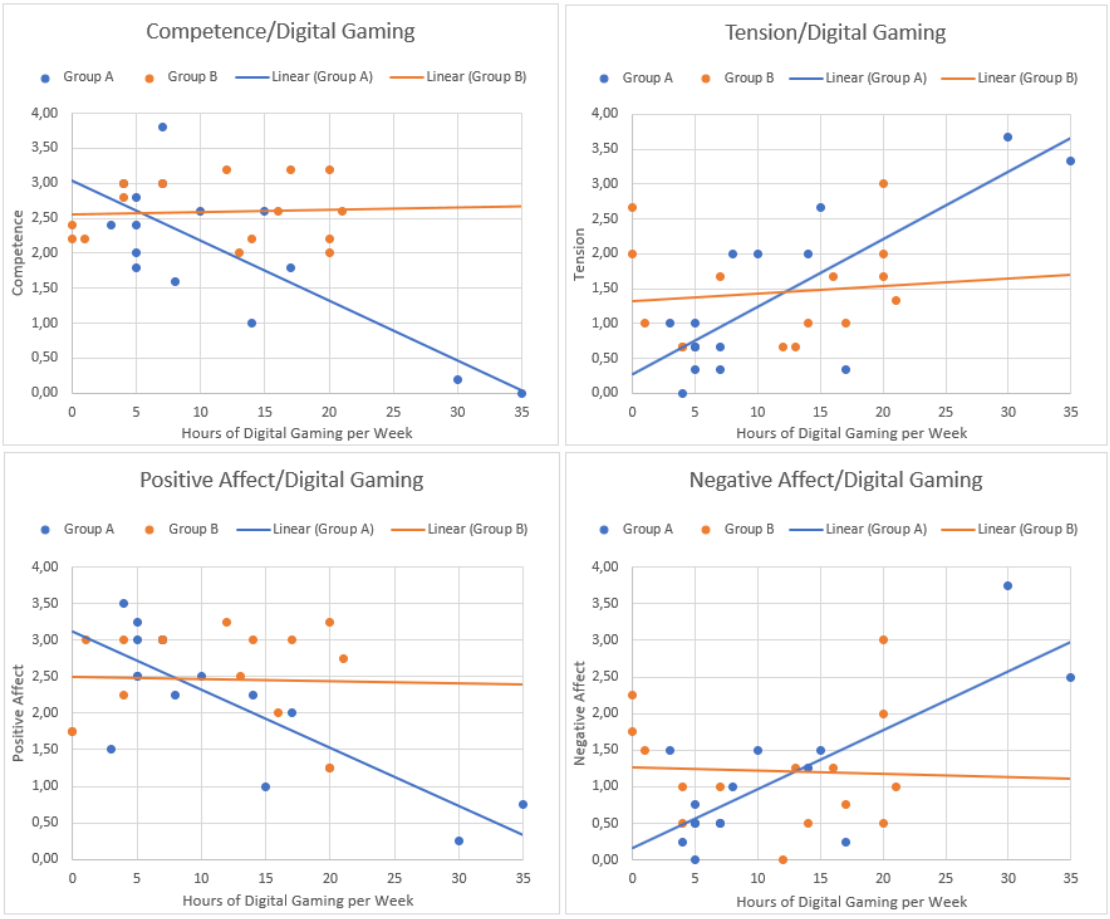


Figure 7.14.: Study I: GEQ competence (top left), tension (top right), positive (bottom left), negative (bottom right) vs. digital gaming (Plecher et al., 2020)

study participants. As students of Egyptology they also perceived the game as a possible learning tool from the beginning, because for them there was a direct comprehensible added value by learning the vocabulary. They memorized the hieroglyphs and words independently from the vocabulary hint. Contrarily the participants in study I were aiming to master the game rather than learning the presented content.

Finally, the acceptance of *HieroQuest* as a learning tool is checked asking the following questions in the feedback section of the post-game questionnaire: *"Is this game useful to learn hieroglyphs?"*. The answer was given on a Likert scale from not-at-all <0> to extremely <4> The result was an average of 3.83 (SD=0.37) in group A and an average of 3 (SD=0.94) in group B. From this it can be concluded that Egyptology students who do not have a great affinity for digital games, attested *HieroQuest* great potential and evaluate it as a useful learning tool.

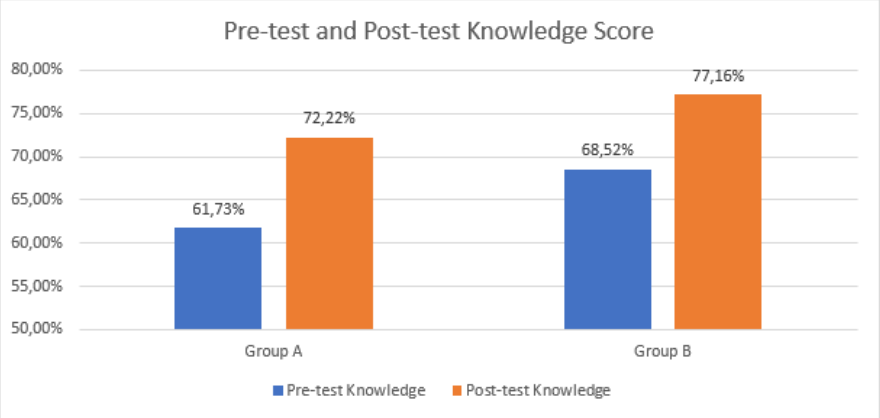


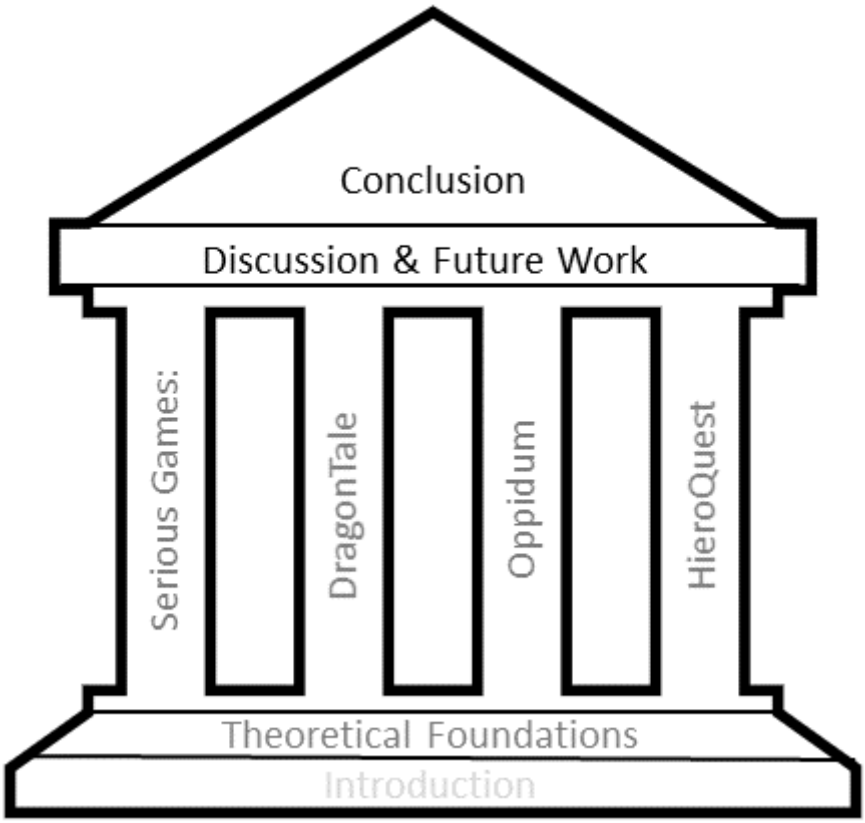
Figure 7.15.: Study II: Pre-test and post-test results for both groups (Plecher et al., 2020)

7.5. Summary

In this chapter we described the development of *HieroQuest*, a Serious Game for learning Egyptian hieroglyphs. We have combined an escape game with learning content, thus combining progress in the game with knowledge gain. Additionally, we have integrated one of the oldest stories of mankind *The Story of the Shipwrecked Sailor* into the game. Consequently, the player engages with the intangible Egyptian cultural heritage in the form of language and literature while playing the game. Subjects with different levels of experience and prior knowledge participated in the studies. The students of the Games Engineering program had no prior knowledge of hieroglyphs. In contrast, students in the Egyptology program had considerably less gaming experience. The game was designed to support the players with hints when they encountered problems in order to avoid overwhelming them. The results of the studies show that *HieroQuest* can transfer knowledge to both groups of participants regardless of prior knowledge. Participants without prior knowledge of hieroglyphs were motivated by the game to engage with the learning content and learned unintentionally during the game. The Egyptology students learned the game controls and increased their knowledge of hieroglyphs during the game. Furthermore, we investigated the differences in knowledge gain depending on whether the vocabulary hint was permanently displayed or autonomously looked up in the in-game dictionary. We found that in the group without prior knowledge, autonomous use had a significantly positive effect on knowledge transfer, player experience, and sense of competence. Because the students of Egyptology were already intrinsically motivated to learn hieroglyphs, no effect could be found in this group. In the questionnaire they stated that they would use *HieroQuest* as a learning tool in their course.

Part III.

Discussion, Future Work and Conclusion (*Entablature*)



8. Discussion and Future Work

Serious Games are meant to combine the playful world of entertainment with the world of learning. We attempted to achieve this goal regarding cultural heritage in different ways with three separate games on different topics. The main research question was:

- **Can Serious Games transfer knowledge about intangible cultural heritage?**

Based on a preliminary study and two detailed studies, we can confirm that all three Serious Games can transfer knowledge about cultural heritage.

DragonTale is dealing with knowledge about intangible cultural heritage in form of the Japanese language. By playing the game, the 10 participants learned according to the informal study different Kanji including their meaning, their correct notation, and their possible combinations. They were able to answer the questions about the learning content correctly in an average of at least 72%. A larger study will be carried out. In addition, the game will be expanded in the future with more levels with additional Kanji. The story of the two protagonists should motivate the players to play this Serious Game even over a longer period of time. The motivation will be increased if the players can influence the story by autonomous decisions. The same could be promoted if the players could change abilities, weapons or items of clothing of Yuni and Ryu to adress the player's creativity

Oppidum is a Serious-AR-Game about the history and culture of the Celts. By using AR, classic board game elements are combined with digital gameplay. Historically accurate 3D models of Celtic buildings provide the player with information about the tangible cultural heritage of the Celts. A study examined the impact of single- and multiplayer on knowledge transfer through two different test groups. 24 test persons played one game mode each in two groups of equal size. We found that the players in both game modes had a significant knowledge gain. Group (M)ultiplayer reached an average score of 49.2% (SD=0.22) in the pre-test and could increase the achieved score on average to 75.8% (SD=0.15) in the post-test. Group (S)ingle-player reached an average score of 45.8% (SD=0.14) and could increase the achieved score on average to 65.8% (SD=0.17) in the post-test. Most of the participants had a general affinity to gaming (Group M: M=5.75, SD=1.36; Group S: M=5.42, SD=1.51) and, on average, a particular experience with AR (Group M: M=4.08, SD=2.31; Group S: M=3.50, SD=1.17)

rated on a scale from not-at-all <1> to very much <7>. The study could be conducted at the university before the pandemic. A tablet and the necessary markers were provided to each participant. Due to these reasons, there were no technical difficulties in the use of AR, in contrast to the DragonTale pre-study. The participants appreciated the possibility of viewing archaeological reconstructions in a game in this way. Therefore, we are currently working on a game called *LegionARius*, which deals in a similar way with the cultural confrontation of Romans and Germanic tribes at the Limes.

However, it was criticized that after playing for a longer period of time, holding the tablet for scanning or viewing the 3D models becomes uncomfortable. The development of AR glasses and headsets is progressing. With their help, players could inspect the buildings more easily. The cumbersome holding of the tablet would thus be eliminated.

HieroQuest teaches the players hieroglyphs in the form of an escape game and gives insights into Egyptian intangible cultural heritage by incorporating one of the oldest recorded stories of mankind - the *Story of the Shipwrecked Sailor*. Several studies were conducted during the iterative development process.

In addition to gaming-experienced attendees, students of Egyptology participated in the main study. As a consequence, it was possible to look at the effects of the game on players with different levels of prior knowledge. The participants without prior knowledge about hierogylphs played the game in two groups (A&B) with different levels of autonomy. In both groups a clear increase in knowledge could be measured. Group A reached a knowledge score of 61.4% (SD=0.12) and group B reached a knowledge score of 73.3% (SD=0.09).

The students of Egyptology played also the game in two separated groups. This time we did a pre-test to evaluate the prior knowledge. Group A achieved a knowledge score of 61.7% (SD=0.10) in the pre-test and group B scored 68.5% (SD=0.12). After evaluating the post-game questionnaire the average knowledge score was 72.2% (SD=0.14) for group A and 77.2% (SD=0.11) for group B. In both groups a clear knowledge gain could be measured.

The study, with participants of varying levels of prior knowledge, demonstrated the importance of Serious Games helping and supporting the player in more than just the learning domain to avoid overwhelm. Future iterations of *HieroQuest* are thus designed to have the game adapt to the player. Consequently, it is a shift from static play to dynamic difficulty adaptation (Herber, 2020). The game collects data about the player's skills and knowledge, and then adjusts the difficulty of the game and learning domains in each new room. This is to ensure that the game provides an appropriate challenge at all times that does not over- or underchallenge the player. This approach follows the combined flow model (see Figure 2.11).

We also work on the future use of AR and VR to teach hieroglyphis, for example a VR version of *HieroQuest* to increase the immersion. Furthermore, the project AR-sinoë (Plecher, Eichhorn, Seyam, & Klinker, 2020) was developed. This serious app makes it easier to learn hieroglyphs with the help of machine learning and AR. The app

analyzes handwritten hieroglyphs and, after detection, augments the transliteration or the corresponding object on top of it.

Now we will look at the individual research questions of each game:

- *DragonTale*: **What impact does AR have on the transfer of knowledge in a Serious Game about Japanese Kanji?**

An improvement in knowledge transfer through AR could not be determined. The study could not be conducted at the university and the participants had little experience in using AR. As a result, the participants were not able to solve the technical problems by themselves. Due to the decentralized conduct of the preliminary study, the participants had to rely on their own devices. It is also possible that the technical difficulties led to excessive demands (see flow, section 2.2.4) and consequently to less knowledge gain. A Serious Game can only transfer knowledge efficiently if the use of the technology is not an obstacle. Consequently many people, who do not have a particular affinity for the technology also do not have any experience with AR. Problems with devices, markers or lighting can lead to a decrease in motivation. The technology and also the experience of the players will change in the coming years. Therefore, *DragonTale* with AR might not cause any more technical problems in the foreseeable future.

- *Oppidum:* **What influence does the single and multiplayer mode have on the effects of the Serious Game?**

To determine whether the game mode affects knowledge transfer, we first look at the knowledge gain per group. The knowledge gain is expressed by the difference of the knowledge scores from pre- and post-test. Group M has gained 26.7% (SD=0.23) and group S 20.0% (SD=0.18). This does not represent a significant difference between the groups (t=2.074, p=0.438).

To analyze the influences of the game mode on the player experience and the motivation of the player to engage with the learning content, the PXI questionnaire was used. In the study, the multiplayer mode achieved the higher scores in almost all categories. However, these were not significant.

In the current version, direct player interaction is limited to QuizWar. Additional game mechanics of this type could increase the influences of the game mode. Nevertheless, it is important that new game mechanics must be also available in single-player mode in order to conduct a further study. One possibility would be to introduce a trading system. Players can offer their goods or buy and trade other items. In multiplayer mode, this could happen by exchanging cards that act as markers. This trading system could be simulated in single-player mode.

- *HieroQuest:* **What impact does the autonomous use of a game mechanic have on learning success in a Serious Game?**

We investigated the differences in knowledge gain depending on whether the vocabulary hint was permanently displayed or autonomously looked up in the in-game dictionary. We found that in the group without prior knowledge, autonomous use had a significantly positive effect on knowledge transfer, player experience, and sense of competence. If, on the other hand, the hint was shown permanently to the group without prior knowledge, this led to underchallenge and boredom according to the flow concept.

No effect of this kind could be found in the group with the students of Egyptology, because they were already intrinsically motivated to learn hieroglyphs. Due to less gaming experience, game control continued to be a challenge. For Serious Games, it is important to allow the player to make decisions as autonomously as possible, as long as the challenge and skills match. The players decide for themselves if they need a hint. The hint system then should provide as much assistance as the player needs, rather than directly providing the solution, again to avoid underchallenging.

9. Conclusion

The first part of this thesis laid the theoretical foundation. The development of Serious Games is complex, since serious elements must be interwoven with game elements. In addition, the game genre must be chosen to match the learning content, as information presentation and retrieval must be comprehensible to the player and seamlessly integrated into the game. The game designers have to choose the game mechanics carefully, as they enable both the player experience (motivation) and, in combination with learning mechanics as so-called serious game mechanics, the transfer of knowledge. This effect can be useful to convey information and knowledge about cultural heritage.

In the second part, three Serious Games were presented, which addressed different topics in the field of cultural heritage with various combinations of game mechanics. *DragonTale* as an adventure game with a focus on story conveys Japanese Kanji. *Oppidum*, a management and construction game for single and multiplayer, uses AR to integrate both intangible and tangible Celtic cultural heritage in a historically accurate way. *HieroQuest* teaches the player hieroglyphs in the form of an escape game.

It was found that all three games transferred knowledge about cultural heritage to the players. Insights were also gained about the game mechanics used. AR is suitable for teaching both characters and archaeological reconstructions. However, the players should already have experience in using this technology or have the possibility to get technical assistance. The choice of mobile devices and the quality of the markers has an additional influence on the game experience. The use of a multiplayer mode leads to increased values in terms of knowledge gain as well as player experience compared to the single-player mode. The effect can probably be increased by even more possibilities of social interaction. In *HieroQuest*, it was found that a higher level of autonomy leads to improved knowledge transfer. By including study participants with different levels of prior knowledge regarding the game and learning content, it became clear that in the development of future Serious Games, more attention must be paid to dynamic difficulty adjustment in order to provide a learning experience for as many players as possible. If it is possible to make learning work in a playful and almost subconscious way, Serious Games are also a solution to many current problems. Especially in times of the pandemic, when schools and museums are closed, Serious Games can transfer knowledge in a playful way.

A. Appendix

Oppidum Evaluation

Oppidum is an augmented reality serious game about the life & history of the Celts. This survey will help to contribute to a better understanding of Serious Games and der value to learning. Thanks for participating!

*Required

1. What is your gender? *

   Mark only one oval.

   - ◯ Male
   - ◯ Female
   - ◯ Prefer not to say

2. How old are you? *

   _____

3. How experienced are you with video games? *

   Mark only one oval.

	1	2	3	4	5	6	7	
not at all	◯	◯	◯	◯	◯	◯	◯	very experienced

4. Identify your player type at http://matthewbarr.co.uk/bartle and enter the abbreviation provided in the result page (e.g. "EKAS") *

   _____

5. Mark the number between 1 and 7 that describes you the best [strongly disagree (1) - (7) strongly agree] *

   Mark only one oval per row.

	1	2	3	4	5	6	7
I frequently play video games.	◯	◯	◯	◯	◯	◯	◯
I frequently play board games.	◯	◯	◯	◯	◯	◯	◯
I have used games before as a means to learn.	◯	◯	◯	◯	◯	◯	◯
I have experience with Augmented Reality applications	◯	◯	◯	◯	◯	◯	◯

Knowledge Pre-Assessment

This section evaluates how much you already know about the Celts.

6. Mark the number between 1 and 7 that describes you the best [strongly disagree (1) - (7) strongly agree] *

   Mark only one oval per row.

	1	2	3	4	5	6	7
I am interested in early european history.	◯	◯	◯	◯	◯	◯	◯
I have general knowledge about early european history.	◯	◯	◯	◯	◯	◯	◯
I have general knowledge about the Celts.	◯	◯	◯	◯	◯	◯	◯

7. How familiar are you with the Celts? *

Mark only one oval.

- ( ) I've heard of them, but don't know who they were.
- ( ) I have some idea of who they were, but it's not very clear.
- ( ) I know who they were, and have a general idea about their life and history.
- ( ) I know who they were, and could give detailed facts about their life and history

Questions about the Celts

8. When did Celts of Iron Age approximately live? *

Mark only one oval.

- ( ) 1200BC-400BC
- ( ) 800BC-0
- ( ) 200BC-500AC
- ( ) 400AC-1200AC

9. How did the majority of Celts live? *

Mark only one oval.

- ( ) They were mostly nomads
- ( ) They lived in Celtic villages and fortified settlements
- ( ) Distributed in cities of geater nations of that time
- ( ) They lived in huge Celtic cities

10. Name two important trading goods exported by the Celts. *

_____

11. Mark all terms that correspond to tranditional festivals of the Celts. *

Tick all that apply.

- [ ] Fehu
- [ ] Beltaine
- [ ] Imbolg
- [ ] Sowilo
- [ ] Easter

12. What was the Celts' primary way of obtaining food? *

Mark only one oval.

- ( ) Hunting and Gathering
- ( ) Agriculture
- ( ) Raiding
- ( ) Trading

13. How confident are you about the correctness of your answers of the "Questions about the Celts" section? *

Mark only one oval.

	1	2	3	4	5	6	7	
not at all confident	◯	◯	◯	◯	◯	◯	◯	very much confident

Before Playing

14. Before you start playing, please enter the 4 digit id provided in the main menu of the game, so we can link the survey results to your in-game statistics *

_____

15. Which mode do you play? *

Mark only one oval.

- ◯ Singleplayer
- ◯ Multiplayer

Let's Play!

Now is the time to play Oppidum. Once you've finished playing the game, you can continue to fill out the survey. Have fun!

Game Experience

This section asks questions about your game experience in Oppidum. Remember that there are no right or wrong answers, just answer as accurately as possible.

The scale reaches from "don't agree at all" (1), over "somewhat agree" (4), to "strongly agree" (7). Mark the number between 1 and 7 that best describes your experience.

16. Describe your game experience [strongly disagree (1) - (7) strongly agree] *

Mark only one oval per row.

	1	2	3	4	5	6	7
I felt capable while playing the game.	◯	◯	◯	◯	◯	◯	◯
I grasped the overall goal of the game.	◯	◯	◯	◯	◯	◯	◯
The game was not too easy and not too hard to play.	◯	◯	◯	◯	◯	◯	◯
Playing the game was meaningful to me.	◯	◯	◯	◯	◯	◯	◯
I could easily assess how I was performing in the game.	◯	◯	◯	◯	◯	◯	◯
I was no longer aware of my surroundings while I was playing.	◯	◯	◯	◯	◯	◯	◯
The goals of the game were clear to me.	◯	◯	◯	◯	◯	◯	◯
Playing this game was valuable to me.	◯	◯	◯	◯	◯	◯	◯
I felt I was good at playing this game.	◯	◯	◯	◯	◯	◯	◯
I appreciated the aesthetics of the game.	◯	◯	◯	◯	◯	◯	◯
The game felt relevant to me.	◯	◯	◯	◯	◯	◯	◯
It was easy to know how to perform actions in the game.	◯	◯	◯	◯	◯	◯	◯
I felt a sense of freedom about how I wanted to play this game.	◯	◯	◯	◯	◯	◯	◯
The challenges in the game were at the right level of difficulty for me.	◯	◯	◯	◯	◯	◯	◯
I enjoyed the way the game was styled.	◯	◯	◯	◯	◯	◯	◯
The actions to control the game were clear to me.	◯	◯	◯	◯	◯	◯	◯
The game gave clear feedback on my progress towards the goals.	◯	◯	◯	◯	◯	◯	◯
I wanted to explore how the game evolved.	◯	◯	◯	◯	◯	◯	◯
The game was challenging but not too challenging.	◯	◯	◯	◯	◯	◯	◯
I understood the objectives of the game.	◯	◯	◯	◯	◯	◯	◯
I thought the game was easy to control.	◯	◯	◯	◯	◯	◯	◯
I felt eager to discover how the game continued.	◯	◯	◯	◯	◯	◯	◯
The game informed me of my progress in the game.	◯	◯	◯	◯	◯	◯	◯
I felt a sense of mastery playing this game.	◯	◯	◯	◯	◯	◯	◯
I felt free to play the game in my own way.	◯	◯	◯	◯	◯	◯	◯
I was immersed in the game.	◯	◯	◯	◯	◯	◯	◯
I wanted to find out how the game progressed.	◯	◯	◯	◯	◯	◯	◯
I liked the look and feel of the game.	◯	◯	◯	◯	◯	◯	◯
I felt like I had choices regarding how I wanted to play this game.	◯	◯	◯	◯	◯	◯	◯
I was fully focused on the game.	◯	◯	◯	◯	◯	◯	◯

17. When playing Oppidum, did you feel more like interacting with a "game environment" or a "learning environment"? *

Mark only one oval.

	1	2	3	4	5	6	7	
learning environment	◯	◯	◯	◯	◯	◯	◯	game environment

Knowledge Post-Assessment

This section evaluates if Oppidum did a good job in conveying knowledge about the Celts.

18. Mark the number between 1 and 7 that describes you the best [strongly disagree (1) - (7) strongly agree] *

Mark only one oval per row.

	1	2	3	4	5	6	7
I am interested in early european history.	◯	◯	◯	◯	◯	◯	◯
I have general knowledge about early european history.	◯	◯	◯	◯	◯	◯	◯
I have general knowledge about the Celts.	◯	◯	◯	◯	◯	◯	◯

19. How familiar are you with the Celts? *

Mark only one oval.

- ◯ I've heard of them, but don't know who they were.
- ◯ I have some idea of who they were, but it's not very clear.
- ◯ I know who they were, and have a general idea about their life and history.
- ◯ I know who they were, and could give detailed facts about their life and history

Questions about the Celts

20. How did the Celts settle most private & public disputes? *

Mark only one oval.

- ◯ The chieftain decided
- ◯ A jury decided
- ◯ The druid decided
- ◯ A judge decided

21. What was the Celts' primary way of obtaining food? *

Mark only one oval.

- ◯ Hunting and Gathering
- ◯ Agriculture
- ◯ Raiding
- ◯ Trading

22. When did Celts of Iron Age approximately live? *

Mark only one oval.

- 1200BC-400BC
- 800BC-0
- 200BC-500AC
- 400AC-1200AC

23. Name two important trading goods exported by the Celts. *

_____

24. How was Celtic leadership organized? *

Mark only one oval.

- They had no organized leadership
- Ruled by a king from a central place
- Ruled by a rich chieftain per princedom
- Ruled by one commonly elected leader

25. How did the majority of Celts live? *

Mark only one oval.

- They were mostly nomads
- They lived in Celtic villages and fortified settlements
- Distributed in cities of geater nations of that time
- They lived in huge Celtic cities

26. Name two trading partners of the Celts. *

_____

27. Mark all terms that correspond to tranditional festivals of the Celts. *

Tick all that apply.

- [ ] Fehu
- [ ] Beltaine
- [ ] Imbolg
- [ ] Sowilo
- [ ] Easter

28. What did the Celts use their iron for? (name two) *

_____

29. How did the Celts bury their dead? *

Mark only one oval.

- In round grave hills
- In lakes and rivers
- Burnt in huge funeral fires
- In deep caves

30. How confident are you about the correctness of your answers of the "Questions about the Celts" section? *

Mark only one oval.

	1	2	3	4	5	6	7	
not at all confident	◯	◯	◯	◯	◯	◯	◯	very much confident

Comments

If there is anything you wanted to let us know, here is the place for it!

31. What do you think about games as a learning platform? Would you play games like Oppidum in your free time?

32. Did Augmented Reality improve the game experience for you?

33. Did you especially like something?

34. Did you especially dislike anything?

35. Do you have suggestions for improvement?

HieroQuest Questionnaire

Pre-Game Questionnaire

1. Select the correct Transliteration corresponding to the Hieroglyph shown:

t | d | b | NONE

2. Select the correct Transliteration corresponding to the Hieroglyph shown:

p | g | d | NONE

3. Select the correct Transliteration corresponding to the Hieroglyph shown:

st | m | p | NONE

4. Select the correct Transliteration corresponding to the Hieroglyph shown:

jni | rkḥ | ḥ.t | NONE

5. Select the correct Transliteration corresponding to the Hieroglyph shown:

km | nbw | ḫt | NONE

6. Select the correct Transliteration corresponding to the Hieroglyph shown:

š | w | f | NONE

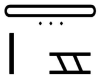
7. Select the correct Transliteration corresponding to the Hieroglyph shown:

d^{ς}	dd	sdm	NONE

8. Select the correct Transliteration corresponding to the Hieroglyph shown:

t	k	b	NONE

9. Select the correct English translation corresponding to the Hieroglyph shown:



SHIP SEE ISLE NONE

10. Select the correct English translation corresponding to the Hieroglyph shown:

SNAKE VIPER BASIN NONE

11. Select the correct English translation corresponding to the Hieroglyph shown:

WOOD MOUTH BASIN NONE

12. Select the correct English translation corresponding to the Hieroglyph shown:

SHIP BREAD STRETCH NONE

13. Select the correct English translation corresponding to the Hieroglyph shown:

SHIP SKY WATER NONE

14. Select the correct English translation corresponding to the Hieroglyph shown:

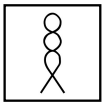
QUAILCHICK VULTURE OWL NONE

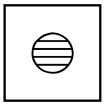
15. Select the correct English translation corresponding to the Hieroglyph shown:

OWL VULTURE QUAILCHICK NONE

16. Select the correct Hieroglyph corresponding to the Transliteration shown:

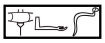
ḫ




NONE

17. Select the correct Hieroglyph corresponding to the Transliteration shown:

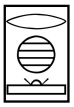
nšn.j




NONE

18. Select the correct Hieroglyph corresponding to the Transliteration shown:

rḫ




NONE

19. Select the correct Hieroglyph corresponding to the Transliteration shown:

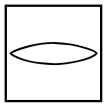
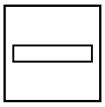
mꜣꜣ




NONE

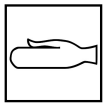
20. Select the correct Hieroglyph corresponding to the Transliteration shown:

š




NONE

21. Select the correct Hieroglyph corresponding to the Transliteration shown:

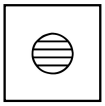
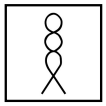
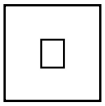
r

NONE

22. Select the correct Hieroglyph corresponding to the Transliteration shown:

ḥ




NONE

23. Select the correct Hieroglyph corresponding to the Transliteration shown:

f

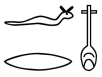



NONE

24. Select the correct English translation corresponding to the Hieroglyph shown:

100 10 1000 NONE

25. Select the correct English translation corresponding to the Hieroglyph shown:



SAY GOOD KNOW NONE

26. Select the correct English translation corresponding to the Hieroglyph shown:

HEAR SEE STRETCH NONE

27. Select the correct English translation corresponding to the Hieroglyph shown:

WATER WELL BASIN NONE

HieroQuest Evaluation

Post-Game Questionnaire

1. Describe your game experience from <not at all - 0> to <extremly - 4>:

	0	1	2	3	4
I felt content	◯	◯	◯	◯	◯
I felt skilful	◯	◯	◯	◯	◯
I was interesed in the game's story	◯	◯	◯	◯	◯
I thought it was fun	◯	◯	◯	◯	◯
I was fully occupied with the game	◯	◯	◯	◯	◯
I felt happy	◯	◯	◯	◯	◯
It gave me a bad mood	◯	◯	◯	◯	◯
I thought about other things	◯	◯	◯	◯	◯
I found it tiresome	◯	◯	◯	◯	◯
I felt competent	◯	◯	◯	◯	◯
I thought it was hard	◯	◯	◯	◯	◯
It was aesthetically pleasing	◯	◯	◯	◯	◯
I forgot everything around me	◯	◯	◯	◯	◯
I felt good	◯	◯	◯	◯	◯
I was good at it	◯	◯	◯	◯	◯
I felt bored	◯	◯	◯	◯	◯
I felt successful	◯	◯	◯	◯	◯

2. Describe your game experience from <not at all - 0> to <extremly - 4>:

	0	1	2	3	4
I felt imaginative					
I felt that I could explore things					
I enjoyed it					
I was fast at reaching the game's targets					
I felt annoyed					
I felt pressured					
I felt irritable					
I lost track of time					
I felt challenged					
I found it impressive					
I was deeply concentrated in the game					
I felt frustrated					
It felt like a rich experience					
I lost connection with the outside world					
I felt time pressure					
I had to put a lot of effort into it					

3. Select the correct Transliteration corresponding to the Hieroglyph shown:

ḏd | sḏm | ḏr | NONE

4. Select the correct Transliteration corresponding to the Hieroglyph shown:

nbw | km | ḫt | NONE

5. Select the correct Transliteration corresponding to the Hieroglyph shown:

jni | rkḫ | ḫ.t | NONE

6. Select the correct Transliteration corresponding to the Hieroglyph shown:

t | d | b | NONE

7. Select the correct Transliteration corresponding to the Hieroglyph shown:

g | p | d | NONE

8. Select the correct Transliteration corresponding to the Hieroglyph shown:

t | b | k | NONE

9. Select the correct Transliteration corresponding to the Hieroglyph shown:

m | p | st | NONE

10. Select the correct Transliteration corresponding to the Hieroglyph shown:

w	*š*	*f*	NONE

11. Select the correct English translation corresponding to the Hieroglyph shown:

SHIP SKY WATER NONE

12. Select the correct English translation corresponding to the Hieroglyph shown:

ISLE SHIP SEE NONE

13. Select the correct English translation corresponding to the Hieroglyph shown:

SHIP BREAD STRETCH NONE

14. Select the correct English translation corresponding to the Hieroglyph shown:

VIPER SNAKE BASIN NONE

15. Select the correct English translation corresponding to the Hieroglyph shown:

VULTURE OWL QUAILCHICK NONE

16. Select the correct English translation corresponding to the Hieroglyph shown:

VULTURE OWL QUAILCHICK NONE

17. Select the correct English translation corresponding to the Hieroglyph shown:

BASIN MOUTH WOOD NONE

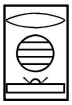
18. Select the correct Hieroglyph corresponding to the Transliteration shown:

nšn.j

   NONE

19. Select the correct Hieroglyph corresponding to the Transliteration shown:

rḫ

   NONE

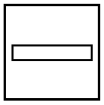
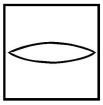
20. Select the correct Hieroglyph corresponding to the Transliteration shown:

mꜣꜣ

   NONE

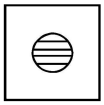
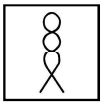
21. Select the correct Hieroglyph corresponding to the Transliteration shown:

š

   NONE

22. Select the correct Hieroglyph corresponding to the Transliteration shown:

ḫ

   NONE

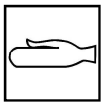
23. Select the correct Hieroglyph corresponding to the Transliteration shown:

f

   NONE

24. Select the correct Hieroglyph corresponding to the Transliteration shown:

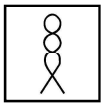
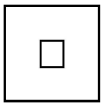
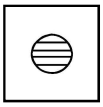
ꜥ




NONE

25. Select the correct Hieroglyph corresponding to the Transliteration shown:

ḥ




NONE

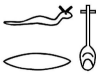
26. Select the correct English translation corresponding to the Hieroglyph shown:

SEE HEAR STRETCH NONE

27. Select the correct English translation corresponding to the Hieroglyph shown:

1000 100 10 NONE

28. Select the correct English translation corresponding to the Hieroglyph shown:



GOOD KNOW SAY NONE

29. Select the correct English translation corresponding to the Hieroglyph shown:

BASIN WELL WATER NONE

30. With which metal is the snake's body plated?

- [ ] Bronze
- [ ] Silver
- [ ] Gold
- [ ] None

31. How many sailors died in the storm?

- [ ] 12
- [ ] 120
- [ ] 140
- [ ] None

32. What is your gender?

- [ ] Male
- [ ] Female
- [ ] Prefer not to say

33. What is your age?

_____

34. How many hours you spend (aprox.) playing digital games per week?

_____

35. Which digital games in particular?

36. What is your course of study?

37. To which degree do you agree with the following statements from <not at all - 0> to <extremly - 4>?

	0	1	2	3	4
I think the game is usefull to learn hieroglyphs					
I would prefer this game over books or flashcards					
I think the game is fun to play					
I think i learned something					
The tutorial successfully explained the basic controls					
The hints provided useful information					
The lexicon is a useful tool					
I used the lexicon often					

38. Which elements of the game you especially liked?

39. Which elements of the game you especially disliked?

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