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# Exploratory and Collaborative Learning Scenarios in Unity-based Virtual Worlds

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# Explorative und kollaborative Lernszenarien in Unity-basierten virtuellen Welten

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# Abstract

Virtual worlds for exploratory, collaborative and immersive learning are a growing field in technology-enhanced learning. Recently, a prototype of a virtual Egyptian world scenario, implemented in Open Wonderland (OWL) developed by Tomes (2015) has demonstrated general approval of collaborative, exploratory, game-based virtual worlds used for learning purposes. Limitations, however, included old-fashioned graphics, poor controls and navigation in the world, and not enough interaction, reward and engagement.

In this thesis, a virtual learning world replicating the first prototype but adapting to the issues raised in the evaluation of this OWL-prototype was developed in Unity to overcome platform-related issues regarding graphics and controls. The level of interactiveness and engagement was improved by implementing concepts to further interact with the subject, and to show and support the progress of achieving the learning tasks. A set of learning tools has been implemented to engage students in learning tasks and collaboration as well as to facilitate teachers to administrate this learning situation. A novel approach was to make the learning tools extensible and reusable for different scenarios in order to ensure flexibility of creating and maintaining learning worlds for teachers. Another important approach was to integrate exploratory, collaborative and challenge-based learning methods in the virtual world to ensure better understanding and learning outcomes. An Egyptian scenario was implemented to showcase and evaluate the learning tools.

An evaluation with 15 participants clearly demonstrated the immersion, motivation and usability of this novel virtual world. While the second prototype showed similar scores for immersion, scores for motivation and usability were higher compared to the outcomes of the OWL evaluation.

# Kurzfassung

Virtuelle Welten für exploratives, kollaboratives und immersives Lernen sind ein wachsender Bereich von Technologie-gestütztem Lernen. Ein kürzlich entwickelter Prototyp eines virtuellen Ägypten-Szenarios, implementiert in Open Wonderland (OWL) von Tomes (2015), hat die allgemeine Eignung zur Verwendung von kollaborativen, explorativen und spiel-basierten virtuellen Welten für Lernzwecke gezeigt. Jedoch war die OWL-Welt durch altmodische Grafiken, schlechte Steuerung und Navigation in der Welt und nicht genug Interaktion, Belohnungen und Engagement eingeschränkt.

In dieser Arbeit wurde eine virtuelle Lernwelt - eine Nachbildung des ersten Prototyps mit Anpassungen bezüglich den aufgeworfenen Problemen der Evaluierung dieses OWL-Prototyps - in Unity entwickelt, um Plattformabhängige Probleme in Bezug auf Grafiken und Steuerung zu vermeiden. Das Level der Interaktivität und Engagements wurde verbessert, indem Konzepte implementiert wurden, die die Interaktion mit dem Lerngegenstand fördern und die den Lernfortschritt anzeigen und unterstützen. Ein Set von Lern-Instrumenten wurde implementiert, um Schüler zu Lernaufgaben und Kollaboration anzuregen sowie Lehrenden das Verwalten dieser Lernsituation zu ermöglichen. Es war ein neuer Ansatz die Lern-Instrumente erweiterbar und wiederverwendbar für verschiedenste Szenarios zu gestalten, um die Flexibilität von Lehrenden bezüglich der Erstellung und Wartung neuer Lernwelten zu unterstützen. Ein weiterer wichtiger Ansatz war explorative, kollaborative und Herausforderungs-basierte Lernmethoden in die Lernwelt zu integrieren, um besseres Lernverständnis und Ergebnisse zu erzielen. Ein ägyptisches Szenario wurde implementiert, um die Lern-Instrumente zu demonstrieren und zu evaluieren.

Eine Evaluierung mit 15 Teilnehmern zeigte eindeutig die Immersion, Motivation und Usability der neuen virtuellen Welt. Während der neue Prototyp ähnliche Werte für Immersion vorwies, waren die Ergebnisse für Motivation und Usability im Vergleich zu den Resultaten der OWL-Evaluierung besser.

# Statutory Declaration

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# Glossary

| | |
|---|---|
| DGBL | Digital game-based learning. |
| LMS | Learning Management System. |
| MLE | Managed Learning Environment. |
| MMOFPSGs | Massively Multiplayer Online First Person Shooter Games. |
| MMOGs | Massively Multiplayer Online Games. |
| MMORPGs | Massively Multiplayer Online Role-Playing Games. |
| MMORTSGs | Massively Multiplayer Online Real-Time Strategy Games. |
| MOOC | Massive Open Online Courses. |
| PLE | Personal Learning Environment. |
| TEL | Technology-Enhanced Learning. |
| VLE | Virtual Learning Environment. |
| VW | Virtual World. |
| WBT | Web-based Training. |

# 1. Introduction

## 1.1. Motivation

New Technology-Enhanced Learning (TEL) approaches continue to emerge to find a way to motivate students to engage in learning tasks. The importance of adapting to new trends is recognized by educational researchers, practitioners, and software designers. There is, moreover, increasing interest in trying to design pedagogical models, which, on the one hand, motivate and engage students but are, on the other hand, easy to use for teachers and do not exceed a moderate budget (Pirker, Guetl, et al., 2013). A growing field is the use of virtual worlds for immersive, collaborative and game-based learning.
Virtual worlds offer a way to implement such pedagogical concepts in an engaging environment, as nearly every scenario or subject can be represented and learning activities featured in a virtual world (Dawley & Dede, 2014). There are countless other advantages, such as multiple users frameworks, real-time communication with other participants and no geographic and content-related restrictions and offering a more immersive way of learning than ever before (OECD, 2011; Kuznik, 2009), which will be more closely discussed in the chapter on virtual worlds. Moreover, as student motivation and participation is closely related to their learning success (Petty, 2004), engaging students in a game with a learning subtext is a method that is more and more used (Wasko et al., 2011).

One of the disadvantages of using virtual learning games, however, is the possible lack of computer and programming skills and knowledge of teachers and instructors that are necessary to create and maintain such a world or the lack of technical support (Gregory et al., 2015). In order to react to this issue this project implements several learning modules that are applicable to multiple scenarios to enable teachers in the creation of virtual learning environments. The second motivation was to have a learning environment that actively engages students by exploring and sharing content to master learning tasks. In more detail, in the scope of this project these tasks were adapted from (Tomes, 2015):

- The revision and redesign of valuable educational activities and processes in an immersive, virtual learning environment.
- The implementation of a set of learning tools for Unity[1] which enabled and supported these learning activities.
- The creation of an exemplary virtual learning world in Unity to showcase and evaluate these tools.

Concluding, the goal of this thesis is the development of a virtual world project in Unity which is an extension of an Egyptian learning world prototype developed in Open Wonderland. The virtual world in Unity addresses some of the issues raised in Open Wonderland such as the graphics enhancements, level of interactiveness and lessons learned from the evaluation of the first prototype. The thesis focuses on the learning tools developed for virtual worlds, with an Egyptian showcase scenario for these tools. It elaborates on the design and development of a virtual world in the platform Unity, compared to the project in Open Wonderland. Several learning concepts such as exploratory, collaborative, challenge-based and game-based approaches were integrated. Users explore the world to find information and share them with other users by collaborating with them in the world. This collaboration is supported by tools embedded in the world, such as Textchat, Itemboard and Chatbot.

## 1.2. Structure

Chapter 2 gives a theoretical overview over reasons and motivation to learn, as it is the essence of learning. Next, different learning styles are discussed, which lead to a section on teaching methods describing conventional learning methods that have been used for years and possible criticisms, as well as newer approaches and developments in the field including different e-learning technologies, emphasising serious games and the use of virtual worlds for educational purposes.

Then, the design of a virtual world integrating previously mentioned learning concepts are discussed in chapter 3. The sections of this chapter focus on the

[1]Unity 3D game engine: https://unity3d.com/

onset situation of this project, the design requirements and -decisions regarding learning modules implemented and choices concerning platform and network. Lastly, the architecture of the project will be presented.

Next, chapter 4 shows the implementation of the project, discussing implementational details of the modules and tools, improvements to previous work, issues and lessons learned in this project. Moreover, future work is mentioned.

Chapter 5 gives on overview over the Egyptian showcase used in order to show the redesign and extension of the issues raised in the previous project, and how such tools can be realized more effectively. Furthermore, alternative scenarios where the implemented tools could be used are suggested.

The following chapter 6 contains information regarding the evaluation of the project. Methodology, participants, procedure and materials will be described and the results discussed. The results are, moreover, compared to the evaluation outcomes of the previous prototype.

Chapter 7 regards the lessons learned throughout the literature research, the implementation and evaluation of the project. Lastly, an outlook and ideas for future work will be given.

# 2. Background

The most important factor regarding teaching and learning success is motivation. By considering the students' reasons to learn motivational measures can be taken, as discussed in the first section of this chapter. On the one hand, there are countless different teaching methods for instructors to orient themselves on. Some of them are traditional and more commonly used; others offer a more modern approach. On the other hand, the students have to be considered. Everybody learns best in a specific way. These different preferences were formulated to so-called *learning styles*.
In following sections a closer look at different learning styles, and some of the conventional teaching methods along with newer teaching approaches will be taken. Many recent methods focus on multimedia supported online learning, ranging from e-learning over game based concepts to 3D virtual environments, which will also be discussed.

## 2.1. Reasons and Motivation to Learn

A student's learning success is closely related to the student's motivation towards a subject. Motivation is a prerequisite for effective learning. Hence, motivation is the key challenge for teachers (Petty, 2004).

According to Petty (2004), reasons for wanting to learn include:

1. **The learned material is useful to the student.** A student's learning motivation depends on his/her interest in being able to something, such as being able to swim like friends or speak French in the holiday. Unfortunately, students often find few applications of content learned in school or college in everyday life.

2. **The qualification for which he/she is studying is useful to the student.** Students need future career qualifications and have long-term aims but it is not the day-to-day short-term motivator.
3. **The learning success increases the student's self-esteem.** This is one of the main motivators, as the sense of achievement is increased by learning success. On the contrary, constant failure is highly demotivating for obvious reasons.
4. **Acceptance of teachers and/or peers is gained.** This point is linked to self-esteem, as on the one hand keeping up with the rest of the class usually leads to acceptance by the teacher and family. On the other hand, boycotting learning is sometimes a sign of rebellion and credited by the peers, which motivates in the wrong direction and should, therefore, be prevented.
5. **Consequences of not learning will be unpleasant.** There are fairly immediate consequences for failure, as good grades lead to satisfaction of the teacher and parents but bad grades lead to make-up tests and extra work.
6. **The material is interesting and appeals to the students' curiosity.** People have a natural curiosity that can be satisfied by new knowledge.
7. **The learning activities are fun.** Even if the material is not of greatest interest to a student, fun and engaging learning activities can create a certain involvement in the matter.

Summing up, there are multiple reasons why students want to learn but they are often either not of immediate significance (long-term goals) or there are factors that encourage not to study even more, such as laziness or peer pressure. Even though it is in their best interest to learn, students do not see it that way quite often. Therefore, it is the teacher's goal to appeal to these reasons to encourage learning and motivate them, as motivation is the key to learning success.

## 2.2. Learning Styles

Everybody learns and processes newly gained information in a different way. To get the best learning results, new material should be presented and taught in a manner every student benefits from, hence a formal classification of these different types of learners was done.

Educational theorist Neil Fleming's main idea behind these learning styles is to create an understanding of the preferences of the learning process of different people. This knowledge can then be matched to teaching strategies. By using the most suitable methods the learner's motivation and, thus, the learning outcome is improved (Fleming & Baume, 2006).
In this section most commonly used approaches to learning style categorization will be discussed and a quick overview of the common characteristics and advice to help learners of each learning style will be given.

A well-known way to classify students into learning styles is based on Stirling's (1987) three categories: visual, aural and kinaesthetic learners (Fleming & Mills, 1992). Among others, Indiana University uses these learning styles to achieve the best results with teaching methods by providing tools to support these different learning approaches. They state that visual learning characteristics include seeing information by using visual aids, such as graphs, charts, pictures. According to Indiana University's definition these learners are good in memorizing and recalling information, but remember things best that were written down. To support this learning type notes should be supplemented by charts and pictures, the bigger picture should be presented before focusing on details and flash cards with written information and colour highlighting can be used for studying. The auditory type learns through hearing or speaking. Information is preferably retained by being told how to do things and then summarizing the main points for memorization. Auditory learners show best results by recording and listening to lectures, repeating new information out loud and discussing it in groups.
The third learning style, kinaesthetic, uses the hands-on approach to learn. The demonstration and exploration of things is easier than the verbal communication of new material. Best results for kinaesthetic learners are achieved by the learning-by-doing approaches, such as experimenting, or at least learning while doing something, like walking or standing (IndianaUniversity, 2015).

Neil Fleming adapts these three main learning styles in his "VARK model of Student Learning" which stands for: Visual, Auditory, Reading/Writing Preference, Kinaesthetic. Alongside the auditory and kinaesthetic learners he differentiates further between visual learners and a reading and writing preference. Whereas the visual type uses images, graphs and charts to understand new information, the reading/writing category learns best by taking notes, reading and formulating newly gained knowledge in essays (Fleming & Mills, 1992).

Other sources differentiate even more and categorize 7 different learning styles. The visual (spatial) and physical (kinaesthetic) is adopted but supplemented by more a subtle approach such as aural (auditory-musical), verbal (linguistic), logical (mathematical), social (interpersonal) and solitary (intrapersonal). Aural and verbal are similar to the auditory learning style mentioned before but distinguish between preferring sound and music, and preferring using words in speech and writing. Physical is the hands-on type, whereas logical prefers reasoning and logic systems. The other two categories, social (preferring learning in groups) and solitary (preferring studying alone) are not present in the VARK-model (LearningStyles, 2015).

There are other famous models of learning styles that have quite different approaches and categories. Felder (1996) discusses four of them in article "Matters of Style". The Myer-Briggs Type Indicator (MBTI) is based on the scales of psychologist Carl Jung's theory of psychological types and classifies students into following categories Felder (1996):

- *"extraverts (try things out, focus on the outer world of people) or introverts (think things through, focus on the inner world of ideas);*
- *sensors (practical, detail-oriented, focus on facts and procedures) or intuitors (imaginative, concept-oriented, focus on meanings and possibilities);*
- *thinkers (skeptical, tend to make decisions based on logic and rules) or feelers (appreciative, tend to make decisions based on personal and humanistic considerations);*
- *judgers (set and follow agendas, seek closure even with incomplete data) or perceivers (adapt to changing circumstances, resist closure to obtain more data)."*

These four categories of each two personas with preferences can be combined to form sixteen different learning style classifications by combing them in different constellations. For example, a student can be ESTJ (extrovert, sensor, thinker, perceiver) (Felder, 1996).

The second is David A. Kolb's learning style model that classifies learners for their preferences on

1. *"how they take information in: concrete experience or abstract conceptualization*
2. *how they internalize information: active experimentalization or reflective observation"* (Felder, 1996).

There are four combinations of preferences. Type 1 (concrete, reflective) is the "Why-type". Learners respond well to explanations of why course material is important to their experience, their interests, and their future careers. Teachers should act as motivators to get good results with type 1 learners. Type 2 (abstract, reflective) ask "What"-questions. Learners appreciate information presented in an organized, logical fashion and benefit from reflection time. They respond to their teacher acting as an expert. Type 3 (abstract, active) is about "How". These learners respond to having opportunities to work actively on well-defined tasks and to learn by trial-and-error in an environment that allows them to feel safe and fail without consequences. The teacher should act as a coach and provide guided practise and feedback. Type 4 (active, concrete) asks the "What if"-question. They like applying course material in new situations to solve real problems. Teachers should let the learner discover things their own way (Felder, 1996).

The Hermann Brain Dominance Instrument (HBDI) is the third model mentioned and classifies students in terms of their relative preferences for thinking. There are four different modes based on the task-specialized functioning of the physical brain and the associated personal characteristics. The classifications and characteristics, respectively, are:

- *"Quadrant A (left brain, cerebral). Logical, analytical, quantitative, factual, critical;*
- *Quadrant B (left brain, limbic). Sequential, organized, planned, detailed, structured;*
- *Quadrant C (right brain, limbic). Emotional, interpersonal, sensory, kinaesthetic, symbolic;*
- *Quadrant D (right brain, cerebral). Visual, holistic, innovative."* (Felder, 1996)

The fourth model Felder discusses is the Felder-Silverman Learning Style Model that distinguishes the following student groups (Felder, 1996):

- *"sensing learners (concrete, practical, oriented toward facts and procedures) or intuitive learners (conceptual, innovative, oriented toward theories and meanings);*
- *visual learners (prefer visual representations of presented material–pictures, diagrams, flow charts) or verbal learners (prefer written and spoken explanations);*
- *inductive learners (prefer presentations that proceed from the specific to the general) or deductive learners (prefer presentations that go from the general to the specific);*
- *active learners (learn by trying things out, working with others) or reflective learners (learn by thinking things through, working alone);*

- *sequential learners (linear, orderly, learn in small incremental steps) or global learners (holistic, systems thinkers, learn in large leaps)."*

This model always has two opposing types of learners and five categories that describe their learning attributes and personal characteristics. It shows a small overlap with the VAK-model discussed before, regarding the visual and verbal learners (Felder, 1996).

Starting in the 1980s and up until today, all four models were tested on engineering students and professors with the following outcome: According to Felder (1996) the MBTI courses are oriented towards

- *"introverts (by using lectures and individual assignments more often than active class involvement and cooperative learning),*
- *intuitors (by focusing on engineering science rather than design and operations),*
- *thinkers (by teaching abstract analysis and neglecting interpersonal considerations),*
- *and judgers (by concentrating on following the syllabus and meeting assignment deadlines rather than on exploring ideas and solving problems creatively)."*

Looking at Kolb's Learning Style, respectively, engineering teachers mainly focus on formal presentation of material (lecturing), a style comfortable for only Type 2 learners. A better execution would be to *"explain the relevance of each new topic (Type 1), present the basic information and methods associated with the topic (Type 2), provide opportunities for practice in the methods (Type 3), and encourage exploration of applications (Type 4)"*, as Felder states. As for the HBDI model engineer professors are of Quadrant C and, thus, focus on left-brain Quadrant A analysis and associated with that analysis Quadrant B methods and procedures, neglecting important skills of quadrant C (teamwork, communications) and quadrant D (creative problem solving, systems thinking, synthesis, and design), which is, therefore, bad for C and D quadrant thinkers. In Felder-Silverman's classification engineering students are mainly intuitive, verbal, deductive, reflective, and sequential learners but hardly ever all five categories at the same time. Hence, they do not receive the education that matches them best (Felder, 1996).

Summing up, there are several different types of learners among students, which were classified into learning styles that respond to the learning preferences. This formal distinction between learners makes it easier for teachers and instructors to present new material in a way suitable for all types. There are, however, multiple methods how to teach different students, which will be discussed in the following chapter.

## 2.3. Teaching Methods

There are countless teaching methods based on multiple pedagogical concepts. The University of North Carolina at Charlotte, for example, lists 150 teaching methods on their homepage. Among them are, on the one hand, commonly practised conventional methods, like lecture, demonstration, discussion, presentation, reading, assignments and many more. On the other hand, it lists newer and diverse approaches like interviews, role playing, use of films and recordings, investigating, experiments, gaming and simulation and others (Carolina, 2015).
These methods vary with regard to group or individual learning as well as passive or active learning. Advantages and disadvantages of these aspects of learning will be explained over the next sections, along with definitions of conventional teaching methods and modern approaches.

Traditional views on learning and teaching often refer to the "learning pyramid" developed in the early 1960s by the National Training Laboratories (NTL) in Bethel, Maine (England, 2015). As shown in figure 2.1, it lists seven levels of teaching techniques and the average student's retention rates. These retention rates illustrate the learner recall of gained knowledge by these various approaches (Peak-Performance-Center, 2015). In some versions the percentages of the categories vary slightly (Strauss, 2015). It is, moreover, shown that lecture, reading, audio-visual and demonstration rate as passive teaching methods and group discussion, practice and teaching others classify as participatory (active) teaching methods. That a high retention of learning is retained by active participation in the learning process is, therefore, clearly illustrated(Peak-Performance-Center, 2015). Today there are multiple criticisms towards the learning pyramid. There is no credible research to support the pyramid, as the NTL can no longer find the original material. Even though the general concept is plausible there are several factors to be taken into consideration with regard to the percentage of the retention factor of each category (Strauss, 2015).

According to Strauss (2015) and Atherton (2015), many variables affect memory retrieval; thus specific percentages can not be assigned without specifying these

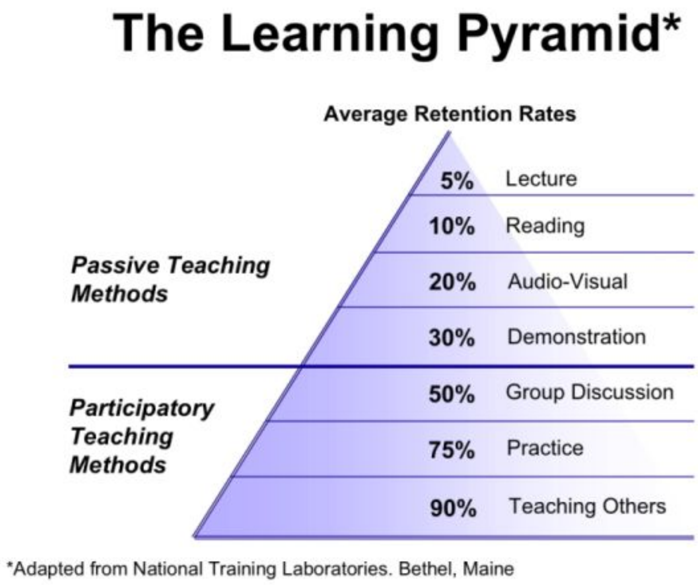


Figure 2.1.: The Learning Pyramid, listing seven levels of teaching techniques and the average student's retention rates (England, 2015)

influencing factors. Among them are:

- what material is recalled (difference between, for example, the audio-visual experiences of gazing out the window and watching an action film)
- the age of the subjects
- the delay between study and test (as the percentage usually drops with time)
- what were subjects instructed to do (difference between asking the subject to read or to summarize as they read)
- how was memory tested (percentage recalled is almost always much higher for recognition tests than recall)
- what subjects know about the to-be-remembered material (if subject has previous knowledge memory will be better) (Strauss, 2015)

Lalley and Miller, authors of "The Learning Pyramid: Does It Point Teachers in the Right Direction?", indicate that *"clear research on retention was discovered regarding the importance of each of the pyramid levels: each of the methods identified by* *the pyramid resulted in retention, with none being consistently superior to the others and all being effective in certain contexts"* (Lalley & R. H. Miller, 2007). Hence, the conclusion is that as all methods have their advantages and disadvantages the teacher's decision making for choosing instructional methods is of key importance.

Sources not based on the learning pyramid identify similar methods and divide them into traditional and modern teaching methods. This distinction is basically in accordance with the passive and active division in the pyramid. Traditional and passive approaches include teacher-centric classrooms, teachers act as knowledge dispenser not facilitators, lack of collaboration and group learning and the focus lies on examinations and results rather than understanding the concepts, whereas, modern and active methods include technology-driven classrooms, continuous evaluation, inquiry-based learning, emphasis on understanding, linking the learned material to life, skill building, collaborative learning, activity-based learning and problem-based learning (Nazzal, 2014).

The next sections will discuss some of these methods in more details.

### 2.3.1. Conventional Teaching Methods

Conventional teaching methods are widely known and used, among them lecture, demonstration and reading. Some of them developed over time, were integrated into other methods or are still valid today. This section will discuss different conventional teaching approaches.

#### Lecture

One of the oldest forms of teaching is the lecture, which dates back to a time when there were no printed books for students and verbal lecturing was the main form of passing on information (Laughton, 2011). Lectures were usually held on a grand scale to reach as many people as possible (Phillips, 2005). Advantages of lectures are exposing students to unpublished, unavailable material and clarifying this information through additional explanation (Network, 2015).

Up until today the dominant mode of teaching are lectures, tutorials and laboratory practical sessions with examinations as assessment. Even though

tutorials are an opportunity for students to discuss a subject, huge amounts of students make small-group tutorials difficult. Usually large-scale lectures are held instead. Laboratory sessions are a good practical practise but often lack in theoretical material (Phillips, 2005). These more active approaches allow teachers to influence students, whereas, lectures are a one-way communication, leaving the student as passive listener (Network, 2015). According to Bligh (1998) obvious disadvantages include that lectures are ineffective to attract the same amount of interest as active approaches, certain presentation methods might not have the same effect on different students, and the attention span of students usually declines after approximately 25 minutes.
Asking students about the quality of lectures, many students state that it is only effective if the lecturer is charismatic and conveys a certain interest in the subject rather than just reading the material off the slides. In that case students could read the slides at home themselves, which is why attendance rates often drop throughout the semester. Students also confirmed that sometimes they look forward to the seminar of the course in order to have explained what they heard but did not understand in the lecture (Laughton, 2011).
Therefore, many students do not seem to understand the material presented, properly, and have to spend time outside the classroom on understanding and long-term retention of the material (Network, 2015) which also has an effect on the standard examinations. Phillips (2005) cites Rowntree (1987) on the typical examinations *"The traditional three-hour examination tests the student's ability to write at abnormal speed, under unusual stress, on someone else's topic without reference to his customary sources of information, and with a premium on question spotting, lucky memorisation, and often on readiness to attempt a cockshy at problems that would confound the subject's experts."* The long-term impact of the new knowledge should be focused on and, thus, the approach to teaching and examining reconsidered. Phillips cites Bransford, Brown and Cocking (1999) that skills and knowledge should be extended beyond the context in which they were learned. Learners need to know they can actually use what they learned. Hence, not only lectures but also the common form of examinations are criticised.
Another author arguing that lectures are not suitable for teaching information, Bligh (1998), finds fault with not promoting thought or inspiring changes in attitudes. Bligh, furthermore, argues that lectures are as effective as other teaching methods but not more effective, as lectures do not stimulate higher-order thinking (Laughton, 2011). Moreover, lectures are a method of teaching where the teacher controls the content and speed, while the student has to learn (Network, 2015; Phillips, 2005). If students fail it is their fault (Phillips, 2005).

To sum up, while lectures are useful to reach a large number of people at the same time to distribute knowledge, it is a one-way form of communication. Students take a passive role by just listening and not otherwise engaging in the lecture, which results in poor understanding and retention as well as lack of independent thinking. This, in turn, leads to bad results in examinations. Although tutorials and laboratory practical sessions generate better results in student understanding, the effort of small-group teaching and teacher-student discussions outranks the usefulness of reaching a big audience which is why lectures are still widely used today.

### Reading

Reading is defined as a solitary activity during which the learner retrieves information and meaning from a printed text (Dhaif, 1990). According to the book "Teaching Today" by Petty (2004), reading is one of the fundamental teaching methods. He describes two approaches to reading originating from Marton and Saljo (1976): surface-level reading and deep-level processing. The first is a passive approach, where students are concerned with:

- *"covering the content*
- *how much they have learned*
- *finding the right answer*
- *assimilating unaltered chunks of knowledge*
- *learning verbatim."* (Petty, 2004)

Deep-level processing, on the other hand, is a mentally active approach where students are concerned with:

- *"the central point*
- *what lies behind the argument*
- *the whole picture*
- *what it boils down to*
- *what it is connected with*
- *the logic of the argument*
- *points that are not clear*
- *questioning the conclusions."* (Petty, 2004)

From these lists it becomes clear that deep-level processing shows to be more successful in exams and to be more versatile.

Petty (2004) also adds a third level, which he calls Zero-level processing where students simply go through the motion of reading but are only concerned with getting it over with as quickly as possible and knowledge will just magically follow.

Although reading aloud to children in first language is used as means of improving their comprehension and encouraging them to read, silent reading is the preferred technique for fluent readers. While students are non-fluent they break sentences into parts due to their anxiety to understand each word, which consequently makes the whole sentence meaningless. In this case reading aloud to them makes sense in order to convey better understanding. This especially applies to children and second/foreign language reading. Fluent readers, on the other hand, should be encouraged to read silently and not be disturbed while doing so in order to achieve higher comprehension in reading larger chunks of text (Dhaif, 1990)

There are also techniques to reading that gain good results. According to Petty (2004), students should skim-read the chapter for an overview, then before reading each section more carefully, ask what is being covered and what should be extracted from it. The next step is to actually read the chapter but the material should be kept in mind in order to answer the questions mentioned before. At the end of each section the student should recite the major points and at the end of each chapter all of it should be reviewed.

Summing up, reading can be a significant learning method when done properly. The student has to be interested in the subject beyond which grade he/she will get for reading and engage with the reading material in order to memorize the information and gain knowledge.

#### Demonstration

Demonstration teaches students how to do a task by providing sequential instructions with the end goal of enabling the learner to do the task alone. It can be used to give examples that enhance lectures or show material and theories in order for students to gain a better understanding of the mechanisms and workings involved. It is an effective way to offer hands-on and inquiry-based opportunities in the classroom (Coffey, 2015). Among others, McKee et al. (2007) have studied the positive effects of showing rather than telling and have found that it enables students to understand new material more quickly and effectively. Involvement engages the students more effectively in the process, allowing them to easier remember steps (Petty, 2004; Kim & Kellough, 1974). Usually the teacher performs the task step-by-step so the student can observe the process of getting to the final result and not only mimic the instructions but recognize a problem solution when unexpected problems occur. After the initial demonstration the teacher's role becomes supporting students in their attempts to recreate the seen, offering guidance and feedback, as well as suggestions for alternative approaches (Coffey, 2015; Eley & Norton, 2004).

Demonstrations are most often found in science and technology courses (Coffey, 2015; Eley & Norton, 2004). There is, moreover, a difference between the hands-on approach and the teacher demonstration. Glasson (1989) conducted a study (*"The effects of hands-on and teacher demonstration laboratory methods on science achievement in relation to reasoning ability and prior knowledge"*) on physical science students which compared the effects of hands-on or teacher demonstration methods on knowledge achievement. A particular focus was on their reasoning ability and whether prior knowledge and ability influences student achievement. The outcome showed that both methods resulted in equal knowledge achievement but the hands-on method led to better results in the problem-solving test (Glasson, 1989).

Concluding, demonstration is an efficient way for students to observe processes. Even better results are reached when students can try demonstrating.

### 2.3.2. Interactive Teaching Methods

While traditional teaching methods are still widely used and accepted there is some criticism to the conventional ways and adaptions are made to improve student learning. As the previous section indicated participatory learning leads to higher motivation and better learning results. Modern teaching methods focus on these active learning techniques, as discussed in the following section.

The assumption made from the learning pyramid that active learning is more effective than passive learning is also backed by Prince (2004), author of *"Does Active Learning Work? A Review of the Research"*. In his study he examined the effectiveness of active learning. In order to establish this, he distinguished between active learning, collaborative learning, cooperative learning and problem-based learning, as described in the following subsection. There are several factors to be considered when trying to analyse active learning:

1. What is being studied
2. Measure of "what works" (Prince, 2004)

The first problem arises because multiple different methods fall under the term "active learning", such as collaborative learning, cooperative learning, problem-based learning and the actual active learning. This can be simplified by focusing on the key elements of active learning methods. For example, the core element of collaborative learning is to work in groups instead of alone, as opposed to active learning where the key element is actively engaging the student in tasks. It is, therefore, important to define precisely what element is being studied. The second issue requires comparing a broad range of learning results and assessing improvements in order to measure which method worked best. Prince stresses that outcomes of this study offer an overview of what worked, on average, on the students examined. Still it might not be replicable in a classroom as all other variables affecting learning can not be controlled in real life situations (Prince, 2004).

According to an educational report by Bonwell & Eison (1991), multiple leaders in the field of education (Cross, 1987) and national reports (Study Group, 1984) urged institutes of higher education, like colleges and universities, to embrace active learning in their teaching, already in the 1980s. Despite these efforts passive teaching persisted until today.
As Faust & Paulson (1998), of California State University, points out with regard to mistrust and hesitation concerning active learning methods, they should not be alternatives but rather enhancements to traditional learning methods, like lectures.

McDonald et al. (2014) summarise several other teaching theories under the terms constructivism, social constructivism, authentic learning and reflective thinking that feature similar aspects. Constructivism places the learner at the centre of learning and allows him/her to construct and develop the knowledge, whereas social constructivism also takes the collaborative nature of learning into account. Authentic learning and reflective thinking involve problem solving and consider the complexity of the real world, as well as promote group reflection and collaborative construction of learning. These approaches show related properties to active learning, collaborative learning and problem-based learning. According to McDonald et al. (2014), when *"[..] learning activities are appropriately designed, students assume an active role in learning by constructing, exploring, negotiating and reflecting on their learning within a virtual community of practice"*.

The following sections will briefly discuss active learning and other active approaches to learning.

### Active Learning

According to Prince (2004), active learning requires the students to engage in meaningful learning activities in the classroom. Key factors of active learning are student activity and engagement in the learning process.
It stands in contrast to the traditional teaching method, lecture, where students passively receive information (Prince, 2004). That does not mean active learning can not be combined with lectures. It only defines any learning activity engaged in by students, apart from listening passively to a lecture. If students are not actively involved in the learning process they will most likely become disengaged and distracted (McDonald et al., 2014). According to Faust & Paulson (1998), active learning *"[..] includes everything from listening practices that help students absorb what they hear, to short writing exercises in which students react to lecture material, to complex group exercises in which students apply course material to 'real life' situations and/or new problems"*. This stands in agreement with the statement of Bonwell & Eison (1991) that students should be motivated to read, write, discuss or be engaged in solving problems. Moreover, they should engage in high-order thinking tasks such as analysis, synthesis and evaluation. Overall these tasks are called instructional activities, as they urge students to think about what they are doing.
To adapt active learning instead of passive learning the instructor should, therefore, focus on the core elements:

- introducing student activity into the traditional lecture, and
- promoting student engagement through collaborative learning, cooperative learning and problem-based learning (Prince, 2004)

### Collaborative Learning

Collaboration is the process of two or more people working together to achieve a common goal. Consequently, collaborative learning describes all ways of students working together in small groups to achieve a common learning goal. This could include memorizing new words in a foreign language, solving a complex mathematical problem or interpreting important pieces of work of literature. The main focus is always on the student interaction opposed to solitary student work (Prince, 2004; D. W. Johnson, 1991).

Students can show different performance, and start out with different knowledge and experience levels and, therefore, help each other as they are responsible not only for their own learning success but also for one another's (Gokhale, 1995). D. W. Johnson (1991) confirms that heterogeneous groups achieve better results for low- and high-performing students. Best sizes for learning groups are between two and six people depending on their prior experience with group work.

The active exchange of ideas, moreover, promotes critical thinking (Gokhale, 1995). Students contribute to the joint goal by sharing knowledge and resources, discussing possible solutions or explaining concepts. As a result they develop deeper understanding and better memorization of the subject. In the process of collaboration students, moreover, gain logical reasoning and thinking skills by articulating or defending ideas (D. W. Johnson, 1991).
Gokhale (1995), moreover, conducted a study with students in technology. It was found that students who participated in collaborative learning performed significantly better on the critical-thinking test than students who studied individually.

But collaboration entails more than just working together. Students must be flexible and compromise while they work to achieve a common goal. Even though they pursue individual goals there should be a sense of shared accountability (Herrmann, 2015). Good group dynamics lead to intrinsic motivation, which means students want to learn to subject and do well for themselves and the others in the group. Another positive side-effect is the reduction of student-student conflicts, as students learn to solve issues among themselves (D. W. Johnson, 1991). Collaborative skills include starting and ending a conversation, responding to prompts, asking for help, asking questions and listening (Herrmann, 2015). Moreover, collaborative learning often results in better outcomes than an individual's work, as different knowledge and ideas are combined (Dillenbourg, 1999).

Collaborative learning is a student-centred approach which means the role of the teacher changes as well. Instead of being the only source of knowledge teachers take the role of facilitators, guiding students in their goal to acquire knowledge and find solutions.

However, collaboration does not happen automatically. A key concept is positive interdependence, which describes the perception that students can either achieve their goals as a group or fail to do so. One student can only succeed if the group does. To promote positive interdependence in groups students have to know that they only reach their goal if everybody in the group does (goal interdependence). Teachers might ask for one product or query one randomly picked person of the group for the result. Another incentive might be if the group achievement influences the individual rewards, such as grades (reward interdependence). Also, if not everyone in the group receives the same information or resources to achieve the goal (resource interdependence), collaboration can be promoted. Another way to ensure collaboration is to use roles and role-specific responsibilities (role interdependence) (D. W. Johnson, 1991).

Collaborative learning is a more general term than cooperative learning, which will be defined below.

### Cooperative Learning

Definitions for cooperative learning are often hardly distinguishable from collaborative learning and the two concepts show multiple similarities and intersections. It is defined as a structured form of group-work where students have a common goal but are assessed individually (Prince, 2004). According to Faust & Paulson (1998), cooperative learning covers formally structured groups of three or more students who are assigned to complex tasks, such as multiple step exercises, research projects or presentations. The three key elements of cooperative learning are positive interdependence, individual accountability and heterogeneous groupings (Faust & Paulson, 1998), which again shows resemblance to collaboration. Positive interdependence requires participation of each group member to achieve a common goal. Individual accountability means that each students is held accountable for his/her actions and contributions to the group. Heterogeneous groups refer to gender and ethnicity as well as academic performance. Also important are equal participation and simultaneous interaction which implies that the more students take part in a conversation or discussion the more students have to negotiate and, thus, learn at a deeper level (Herrmann, 2015).
But the core focus is cooperation rather than competition (Prince, 2004). Gokhale (1995) cites R. T. Johnson & D. W. Johnson (1986) who found evidence that

cooperative teams achieve higher levels of thought and memorize information longer than students who work quietly as individuals.

#### Problem-Based Learning

Prince also mentions problem-based learning in his study, which is also part of active learning and sometimes collaborative or cooperative learning. The assumption is made that by solving everyday problems, learning occurs (Hung et al., 2008). It is an instructional method that introduces problems in the beginning to provide a motivation and context for the learning cycle (Prince, 2004). Students usually work in small groups to solve problems in a self-directed (Prince, 2004) and self-reflective way, as they assume responsibility for - and monitor their their learning progress (Hung et al., 2008). There are, however, studies that show too much self-direction is not leading to good results either, and therefore caution is advised (Prince, 2004). The goal of problem-based learning is to enhance learning by requiring the student to solve problems. Based on a problem case students identify what they know already, what they need to learn to better understand the subject and what learning activities are neccessary (Hung et al., 2008). They then study and collect information individually before returning to the group to discuss and refine their acquired knowledge (Wood, 2003).

Required skills associated with problem-based learning are teamwork, listening, cooperation, respect for collegue's views, self-directed learning and use of resources (Wood, 2003). Gokhale cites Bruner (1985) who finds that collaborative learning methods improve problem-solving strategies as students are confronted with different opinions and interpretations of the given situation (Gokhale, 1995).

### 2.3.3. Technology-Enhanced Teaching

Emerging new technologies diversify the range of existing teaching approaches and offer people who have not reached their full potential with conventional methods new approaches to learning and teaching (Kuznik, 2009). Current emphasis of learning approaches lies on Technology Enhanced Learning (TEL), including Learning Management System (LMS), Personal Learning Environment (PLE) and Massive Open Online Courses (MOOC) (Taraghi et al., 2013).

Emerging technologies such as virtual worlds, serious games, wikis and social networking sites are increasingly accepted as learning and teaching practices (Kuznik, 2009).
Computer-supported learning refers to connecting remote students as well as using technologies to improve face-to-face interactions (OECD, 2011). It, moreover, allows students to be completely independent while highly connected with others at the same time and able to communicate at any time (Garrison, 2011).

There is hardly a job today that does not involve the use of computers or any other technical equipment. Therefore, students should be prepared for the use of such technologies. They can, on the one hand, be an advantage for teachers as students are more and more used to working on computers and are, therefore, more engaged and motivated to work with computers than with conventional teaching tools (Petty, 2004). On the other hand, teachers have to adapt their teaching strategies, among other situations, shifting from pen-on-paper writing to computer-based text production or considering changes in reading from page to screen (Sutherland-Smith, 2002). Other technical equipment includes cameras, video cameras and mobile phones (Petty, 2004). These can be used to create interactive classes.
Computers are, furthermore, a great resource for teachers as they offer countless teaching tools and resources. Via the internet large amounts of free material is available (Petty, 2004). According to Kuznik (2009), *"Mobile technologies and internet can provide access to rich digital media content and facilitate communication with others both local and remote to provide powerful learning experiences that go well beyond the traditional classroom"*. Another way to use computers for teaching purposes are e-education applications.

Two important keywords are Virtual Learning Environment (VLE) and Managed Learning Environment (MLE). A VLE is a network that operates on computers in an institution. Students can log into the system on a school computer or at home to access their work in chunks. Their progress is tracked and their work can be assessed. It also enables teacher student communication. MLEs are all information systems and processes in a school or college that contribute to learning and the management of learning in any direct or indirect way, such as student records (Petty, 2004).

Taraghi et al. (2013) gave examples for these computer-supported technologies. While Web-based Training (WBT) consists of several self-contained learning units that can be worked on by learners, learning management systems support not only the organisation of learning processes by providing learning content, but also evaluation and assessment, as well as administration and communication tools. There are countless examples for LMS; nearly every educational institution uses one, to give just one example: Moodle with over 50,000 registered sites. More individually usable learning platforms are Personal Learning Environments. Learners can integrate and manage distributed online resources with no predefined content. However, it is hard for teachers to assess the progress in PLEs (Taraghi et al., 2013).

In recent years massive open online courses have emerged. These are free online courses offered by various universities for the general public. Even though MOOC platforms, such as Coursera or edX, are widely popular and reached thousands of learners, there are critics who argue that the completion rate of MOOCs is less than 10 percent on average (Jordan, 2013; Fowler, 2013). Further disadvantages of MOOCs mention the time and effort needed to complete a course, lack of pedagogical concepts and interesting courses. Benefits, however, include the breakdown of physical and time zone boundaries, as students from around the world can participate in courses, and the learning can be organized around the students schedule. Moreover, learning success is created through peer discussions and despite the absence of assessment. The biggest advantage is the overall motivational effect (MoocGuide., 2011).

Summing up, e-learning has real advantages compared to traditional learning, regarding communication, collaboration, connectivity of participants and interactivity. Disadvantages, such as the need of a computer and internet disappear these days. Issues that remain are the student's engagement and the learning progress associated with motivation and engagement.
Engagement is closely related to how much motivation is raised by learning tasks. Game-based approaches try to increase the "fun factor" of learning and, thus, increase the motivation and engagement for learning, which the next section will take a more detailed look at.

## 2.4. Digital Game-Based Learning and Serious Gaming

DGBL, serious gaming or edutainment games, are described to be the next wave of technology-assisted learning - a genre that focuses on the learning aspect

in games. There are countless terms for games with an educational purpose depending on the community. Literature shows great distinctions between definitions of these terms, on the one hand, but equivalent use of terms, on the other hand.
This section summarizes common definitions for the terms digital game-based learning, serious gaming and edutainment games, but especially looks at their similarities regarding the use of games for educational purposes and the motivational factor of them. Furthermore, the effectiveness and downfalls of educational games is discussed and objectives for the development of a game-based learning environment are collected.

**Serious Games**

Serious games include all kinds of educational entertainment games and every digital game that has a purpose beyond entertainment. They stand in contrast to purely entertaining games with regard to the advantageous outcome for the player (Ratan & Ritterfeld, 2009).
Serious gaming is an *"active, problem-solving, situated and social form of learning with rapid and differentiated feedback that also promotes the enjoyment of learning"* (Iten & Petko, 2014). The learning content is integrated into the game and story, which increases motivation (seriousgames.de, 2015). They facilitate self-guided, enjoyable and sustained learning experiences, and have no negative or harmful impact (such as addiction or aggression). They are intended to facilitate deep learning and reach a wide audience (Ratan & Ritterfeld, 2009).

Ratan & Ritterfeld (2009) categorized four dimensions in which serious games are defined.

1. Primary educational content:
   The primary educational content is the driving force that makes the game serious not just entertainment, such as academic education, social change, occupation, health, military, and marketing. The categories are self-explanatory as they target a specific educational field, a social or political issue, one occupation or skill set.
2. Primary learning principle:
   The primary learning principle describes that serious games provide an opportunity to explore, experiment and solve problems. There are four categories associated with primary learning principles: practising skills, knowledge gain through exploration, cognitive problem solving and social problem solving.

3. Target age group:
   Concerning the target group there are four age groups: (1) preschool and below, (2) elementary school, (3) middle and high school, and (4) college, adult and seniors.
4. Platform:
   The game's platform also plays an important role in the game's effectiveness. While many serious games are developed for computers, there are several other platforms that can be used, such as Nintendo, Playstation or DVD (Ratan & Ritterfeld, 2009). Other platforms again include mobile devices, among them Android and iOS.

**Edutainment Games**

Literature also uses the term "edutainment" to talk about educational games. To be accurate however, while all edutainment games are serious games, not every serious game is an edutainment game. The definition of serious games extends beyond edutainment including almost every digital game that has a purpose in addition to entertainment, while edutainment encourages specific skill development or reinforcement learning in an entertaining environment (Ratan & Ritterfeld, 2009). The focus lies on teaching certain subjects, concepts or assist in learning a skill while the student plays the game. Subjects and skills or often already known to the student but are practised, for example maths or reading. The entertainment and game elements are often reward for achieving a learning goal (seriousgames.de, 2015).
Edutainment games include digital as well as non-digital educational entertainment games.

**Digital Game-based Learning**

Digital game-based learning is a part of edutainment games. Digital games have become a promising educational medium due to their versatile nature. They are used in several different subjects, such as mathematics, social science, natural science and engineering (N.-S. Chen & Hwang, 2014).
DGBL is used for knowledge acquisition by promoting learning or development of cognitive skills. They are more student-centred, interesting, easy and, therefore, potentially more effective than traditional teaching methods (Papastergiou, 2008). The main emphasis lies on the mixture of serious learning and interactive entertainment (Prensky, 2001).

A DGBL environment should (Erhel & Jamet, 2013)

1. feature a set of rules and constraints and
2. a set of dynamic responses to the learner's actions,
3. be challenging to let the student experience a feeling of self-efficacy,
4. be learning outcome-oriented, and
5. gradually increase in difficulty.

According to Papastergiou (2008) they

1. *"support multi-sensory, active, experimental, problem-based learning,*
2. *they favour activation of prior knowledge given that players must use previously learned information in order to advance,*
3. *they provide immediate feedback enabling players to test hypotheses and learn from their actions,*
4. *they encompass opportunities for self-assessment through the mechanisms of scoring and reaching different levels, and*
5. *they increasingly become social environments involving communities of players"*.

Hence, the student should feel part of the game at all times not concentrate on the learning. The learning should be done involuntarily. It is important that the learning and entertainment part are equally integrated in order to exclude learning programs or purely entertainment games (seriousgames.de, 2015).

Games of all above described categories are designed to promote learning, or the development or practise of skills in a virtual environment (Erhel & Jamet, 2013). Likewise, Corti (2006) argues in his article that serious gaming *"is all about leveraging the power of computer games to captivate and engage end-users for a specific purpose, such as to develop new knowledge and skills"*. Many popular games (such as Guitar Hero, Rock Band or Wii Sports) are, for example, mimicking and practising real-life skills in a virtual environment (Powers et al., 2013). Research showed that deep learning or meaningful learning is reached when learners actively engage in the learning task or information processing (Erhel & Jamet, 2013; Broek et al., 2001).

Digital games are, moreover, an suitable medium to integrate all types of learners, that were described in section 2.2. Contents are visually presented, information can be conveyed in written text or as audio and user can test or practise their skills by doing something in the virtual environment. Pirker & Gütl (2015) confirms that visualizations of concepts can improve understanding of a subject. While Pirker & Gütl (2015) talks about educational simulations this is also applicable for digital games.

**Motivation**

According to Petty, games can produce an intense involvement and a quality of concentration no other teaching method can recreate. Moreover, *"the increase in interest and motivation produced by a short session of game-playing creates a positive feeling towards the subject (and the teacher)"* (Petty, 2004). Engagement in the game and, hence, the learning subject can be promoted by motivation. The learner's motivation is, therefore, key to the learning success in educational games (Erhel & Jamet, 2013). Motivation influences the direction, vigor and persistence of behaviours (Moos & Marroquin, 2010). A powerful learning environment not only elicits deep learning but also enhances the learner's motivation (Erhel & Jamet, 2013).

The entertainment factor of games is a key contributing factor in terms of motivation and engagement (Moos & Marroquin, 2010). By conducting analysis of several studies on motivation the following aspects were categorized: goal orientation, intrinsic-extrinsic motivation, interest and self-efficiency. Another study also refers to the connection between intrinsic motivation and the learning scores in game-based learning (Liu et al., 2011). Intrinsic motivation describes the inner desire to engage in a task out of interest, amusement or the challenge it offers (Erhel & Jamet, 2013) without expecting to gain anything in particular from it, such as rewards (Ronimus et al., 2014). Children's intrinsic motivation towards a game, therefore, contrasts their often noted lack of interest in a curricular subject or learning itself (Papastergiou, 2008).
Other studies focus on the flow theory which describe flow as the subjective engagement in an activity the user experiences (Erhel & Jamet, 2013) which is characterized by *"intense and focused concentration, the merging of action and self-awareness, a sense of control, a loss of reflective self-consciousness, and a distortion of temporal experience"* (Ronimus et al., 2014).
The concept of flow is connected to intristic motivation as *"a person's activity is autotelic, rewarding in itself, and extrinsic outcomes of the activity have little personal significance"* (Ronimus et al., 2014). Sweetser & Wyeth (2005) developed several design criteria for engaging computer games based on the flow theory. Elements that produce flow include concentration, challenge, control, clear goals, feedback, immersion, and social interaction (Ronimus et al., 2014).
Another motivating factor is to give the player choices he/she can take autonomously (Ronimus et al., 2014) to challenge him/her and promote self-

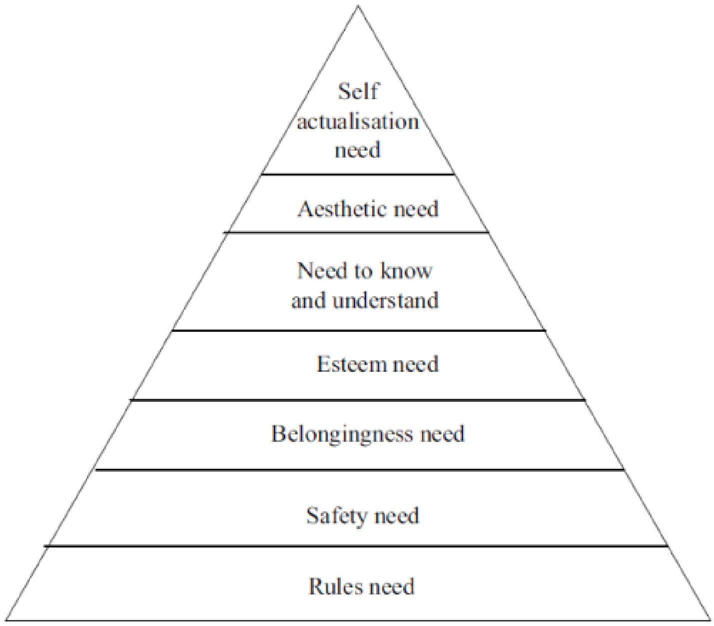


Figure 2.2.: Hierarchy of the player's needs by Siang & Rao (2003)

efficiency. The short amount of training time and immediate possibility to start playing without many instructions are very significant motivators in serious games. Players can find out the right approach by trial and error and are provided the right amount of hints not to get frustrated by making no progress over longer period of time. The emphasis of games with educational purpose should, therefore, be to challenge the player in order to keep him/her motivated (Siang & Rao, 2003). These findings are substantiated by Papastergiou (2008), stating that the game's entertainment characteristics leading to the user's engagement are challenge, fantasy and curiosity. The entertaining nature of the game should, as a result, arouse enough interest in the game that the learner keeps playing. By engaging the player in the game there is an increased chance of motivation and learning success.

Siang & Rao (2003) formulated "motivational" factors of games by adapting Maslow's pyramid of needs to the player's need in terms of motivation, as shown in figure 2.2. At the bottom layer the player's need to understand the rules of the game are of importance. Without having general information about the rules of the game players will immediate become disengaged and stop

playing. The next level describes their need to be safe and secure in the game - their knowledge to stay in the game long enough to participate and win without being knocked out. The belongingness need is the player's need to feel comfortable enough to achieve the game's goal and win, or at least see the possibility of winning. Next they want to feel great playing the game, boost their ego and have full control over the game. In the level after that players need to know and understand more about the game, the strategies, hidden items, etc. and start to look for something more challenging. Aesthetics describe the need for good graphics, visual effects, appropriate music and overall design effect of the game. In the last level of the pyramid, the player wants to be able to do anything he/she wants as long as it conforms to the game's rules (Siang & Rao, 2003).
These principles can be a good guidance for developers of games with educational purpose.

Another aspect of motivation mentioned by Moos & Marroquin (2010) was goal orientation. Literature distinguishes between mastery goals and performance goals. Mastery goals include the desire to master new skills, knowledge or abilities. Performance goals refer to the desire to demonstrate the ability to succeed by exceeding others with as little effort as possible.
In the case of digital games students often focus on either the mastery goal (for example, improving their knowledge about a subject) or performance goals (for example, achieving the highest score) (Moos & Marroquin, 2010).
By considering the student's goals the engagement in the game becomes apparent. The game should, therefore, be designed to prompt users to set and achieve both goals, as the engagement, as well we the learning success plays an important role. Users can then put their effort into learning aspects as well as on the playful components of a learning game (Erhel & Jamet, 2013). Educators, therefore, try to find strategies that combine entertainment with education and the game technology should provide the environment in which serious content can be embedded (Ratan & Ritterfeld, 2009).

Summing up, literature distinguished between serious games, edutainment games and digital game-based learning, among other "game" and "learning" related terms. Serious games are developed for a primary purpose other than entertainment. Edutainment, however, is only a part of serious gaming, adding educational content to digital games, even if the entertainment and motivation is emphasised. Digital game-based learning is a sub-category of edutainment games and includes all digital educational entertainment games.

What all approaches have in common is, that to successfully convey knowledge and skills students have to engage in the game. Key for this engagement is the entertainment factor of the game which promotes motivation. Effective educational games, therefore, should be entertaining, motivating enough to engage the students in the serious learning scenarios of the game. The actual effectiveness of games in education will be discussed in following section.

### 2.4.1. Effectiveness and Downfalls of Educational Games

The main questions raised regarding digital games are

1. if they can prompt deep learning (Graesser et al., 2009) and
2. the effect of motivation on learning (Prensky, 2001; Connolly et al., 2012).

Researchers agree that digital learning games potentially have everything it takes to become an effective learning medium (Erhel & Jamet, 2013; Connolly et al., 2012; Prensky, 2001). Yet there is not enough literature to explicitly confirm the learning effectiveness of games in education. Existing research offers many contradictions and there is lack of formal research and empirical studies regarding the beneficial nature of games for educational purposes (Ratan & Ritterfeld, 2009).
There is literature, however, that recognizes the effectiveness of digital games to increase student motivation and engagement in educational scenarios (Erhel & Jamet, 2013; N.-S. Chen & Hwang, 2014).

In an overview of literature on the matter, studies were mostly equivocal in terms of digital games versus traditional teaching methods. For example, 38 studies reported no difference, while only 27 studies favoured games and 3 favoured traditional methods (Papastergiou, 2008). In another review of studies comparing digital learning games to conventional classroom instructions only about one third concluded games beneficial for learning performance. Similar results were found in studies measuring learning effectiveness of educational games and simulations, compared to conventional learning (Erhel & Jamet, 2013). Another study showed that students using an (English and mathematics) game (for students aged 8-12) could not articulate the underlying (mathematical) concepts afterwards (Papastergiou, 2008).
Many authors (Connolly et al., 2012; Lee & Peng, 2006; Rieber, 2005; Tobias &

J. D. Fletcher, 2008; Lieberman, 2006; Papastergiou, 2009b) expressed reservations regarding the use of digital games for educational purposes.

Opposed to these negative findings, it was shown that educational games and simulations have a positive effect on learning quality and attitude towards learning, compared to conventional learning by Erhel & Jamet (2013). Multiple studies also confirmed the positive effects of learning games on motivation, as well as, learning gains (Connolly et al., 2012; Iten & Petko, 2014; Lee & Peng, 2006; Vogel et al., 2006).
Papastergiou (2008) discusses several studies on games designed for educational purposes, addressing the motivation and, in some cases, the learning effectiveness. A project demonstrates that games increase student motivation and academic success (in mathematics and science education in grades 4-8). In a study (on computer memory concepts for high school students) Papastergiou (2008) showed digital games were more effective than non-gaming approaches with regard to knowledge acquisition and motivation. These findings correspond with studies (on mathematics and science) which showed that the use of educational games contributed to increased academic achievement and motivation compared to traditional lessons (Klawe, 1999; Rosas et al., 2003; Ke & Grabowski, 2007).

The study conducted by Papastergiou (2008) was particularly interesting as it was (1) conducted with high school students, who are harder to motivate than the usual target group of children, (2) using an unusual subject area, and (3) it was compared to another computer-based but not game-based learning system. Point 2 suggests that digital learning can be used for all kinds of different subjects. Powers et al. (2013) reviewed studies on the effect of digital games on information-processing skills. Prior game play experience, age, gender, game conditions (such as genre of the game) were considered in the analysis. The meta-analysis showed that video-game play was consistently and significantly associated with enhanced information processing. There were significant effects of game-play experience on information processing.

The focus of studies often lies in student motivation rather than educational achievements.
Studies on motivation showed that digital game-based learning is more motivational than conventional classroom learning (Erhel & Jamet, 2013). A study on the importance of fun in learning games conducted by Iten & Petko (2014) confirms that while there was a *"correlation between enjoyment and the motivation to continue being engaged with the subject matter of the game, no effect was found with*

*respect to self-assessed or tested learning gains"*. A study on the importance of fun in learning games showed that while motivation and student engagement are important, fun and enjoyment are not directly associated with learning games (Iten & Petko, 2014).
Contradicting these previous reviews there are also authors (Kebritchi et al., 2010) concluding that digital educational games show hardly any motivational benefit (Erhel & Jamet, 2013).

Another issue with educational computer-games is whether they are equally effective and motivational for female and male students. Traditionally games were male-dominated due to their content (often the use of combat and gender stereotypes).
Prior research on domestic computer use resulted in the fact that boys use games and participate in players' communities for the exchange of game-related resources more frequently than girls and are, therefore, more experienced players, more familiar with computing hardware and software and have greater computer confidence and ability (Papastergiou, 2008).
There is too limited research to allow conclusive inferences but studies so far showed important gender differences in student gaming preferences and practices and equivocal findings regarding learning effectiveness in digital games. In the meta-studies Papastergiou (2008) reviewed and conducted boys played more games, made faster progress, had a higher completion rate, developed strategies for information sharing and recognized the embedded mathematics. Boys, moreover, had more prior knowledge of the subject and more experience with computer games. Girls, on the other hand, were more appreciative of a female protagonist, showed interest in different games but less performance in the categories just mentioned than boys. There were no significant differences concerning the achievement of learning gain, the students views of the overall appeal, the quality of the user interface, and the educational value of the game. Other studies also showed that girls have a less positive overall attitude towards technology and video games, and may prefer different kinds of video games than boys (Powers et al., 2013).

These contradictions in literature might stem from the fact that the effects of learning games are influenced by factors such as individual learning characteristics, the learning situation and the topic being taught. Comparing the learning outcomes of people who play educational games to people who learn with conventional teaching aids depend on factors such as format, pace, educational content, teacher's social presence (Erhel & Jamet, 2013).

Current state of research does not allow the definite conclusion that games with educational purpose are beneficial on learning effectiveness or motivation (Erhel & Jamet, 2013). Due to the limited and equivocal findings more studies are needed. First of all, investigations regarding the effectiveness of learning in educational games in terms of concrete curricular objectives within specific subject areas and the motivation of games should be conducted. Moreover, future research should focus on students during high school level (where motivational issues and scholastic competences become more acute) instead of children. Thirdly, comparing educational computer-games to conventional teachings methods implies the replacement of traditional personal tutoring instead of complementing it by games. The difference between computer-based instructions and digital game-based approaches should be analysed. Furthermore, the increased use of games by girls calls for further gender-related studies. Cultural and social aspects might also be of interest, as prior studies were often based in North America or Britain. Lastly, studies could examine whether an increased level of complexity and attractiveness of the game environment would cause more distraction than a simple environment (Papastergiou, 2008).

Several possible solutions were analysed to improve the learning effectiveness of games with educational purpose, such as instructions, feedback, rewards and challenges.

**Instructions**

Instructions may direct students towards educational goals or encourage them to pursue for playful goals. Appropriate instructions can help students target the relevant information in a text.
Literature distinguishes between specific and general instructions. Specific instructions encourage the learner to identify target pieces of information and connect it to their prior knowledge. General instructions prompt learners to use a particular perspective or goal while learning a document (Erhel & Jamet, 2013). For example, results differed when students were asked to read a document in preparation for an exam or just for fun. The first situation resulted in more predictive inferences and paraphrases. The second circumstance resulted in more opinions and personal references (Erhel & Jamet, 2013; Broek et al., 2001). In the context of digital learning-games, instructions can prompt students to actively learn and not just incidentally (Erhel & Jamet, 2013; Greitzer et al., 2007). A study on instructions resulted in better comprehension performance with

learning instructions than entertainment instructions. There were no results regarding memorization. The entertainment perspective prompted too little learning engagement to trigger deep learning (Erhel & Jamet, 2013). Erhel & Jamet (2013), therefore, advised against the use of entertainment-instructions in educational computer-games.

### Feedback

Studies showed that feedback improves recall compared to giving no feedback. There are different kinds of feedback depending on their length, specificity, timing and complexity. Types of feedback are explanatory, corrective feedback and knowledge of correct response feedback (KCR). Corrective feedback entails telling the learner whether their answer is right or wrong. Explanatory feedback provides the right or wrong answer together with explanations (Erhel & Jamet, 2013).
Immediate and clear feedback contribute to a flow experience in the game, which in turn, contribute to the intrinsic motivation in the game (Ronimus et al., 2014; Ke & Abras, 2013). A study by Erhel & Jamet (2013) demonstrates that KCR feedback in combination with entertainment instructions promotes deep learning while enhancing the learner's motivational investment. There were no results regarding memorization. It cannot, however, be concluded that this applies for all forms of feedback (Erhel & Jamet, 2013).

### Challenges and Rewards

Computer games can challenge users with elements of fantasy that rouse their curiosity and are intrinsically motivating. These design principles are proven by findings of studies. In a study conducted in a social game environment the majority of children concluded that challenge is the most important flow element (Ronimus et al., 2014; Inal & Cagiltay, 2007). Games that included challenge levels and rewards produced best results regarding the flow experience (Ronimus et al., 2014; Ke & Abras, 2013). Digital games, moreover, have motivational an engaging aspects due to their immersive and challenging nature combined with their short learning curve and instant feedback/reward system (Siang & Rao, 2003). A study by Ronimus et al. (2014) investigated the effects of challenges and rewards on children's engagement in a game. The reward system encouraged children to play longer sessions but only at the beginning of the training period and not any more after a few sessions. The level of challenge had no effect on children's engagement.

Summing up, there are many contradictory studies about digital games with educational purpose that do not yet give certainty about the effectiveness such games. The impact of educational games on motivation is mostly positive but also needs more evidence. There are several approaches, that were positively tested on enhancing the effectiveness of digital learning-games, such as instructions, feedback, challenges and rewards. However, certain limitations should not be disregarded. Instructions are best when used as learning instructions instead of entertainment instructions. Knowledge of correct response feedback seemed to improve the learner's performance, however other types of feedback were not discussed. Rewards seem motivational to students, whereas the use of challenges is useful in theory but studies resulted in contradictions.
The phenomenon of digital learning games and the discussions of their usefulness, however, goes back quite some time, as discussed in the following section.

### 2.4.2. History of Learning Games

Digital games have become popular as a learning medium in recent years (Erhel & Jamet, 2013). The interest in games in the educational sector may stem from the huge amount of time children and adults spend playing video games (Papastergiou, 2008). On average, children nowadays spend one hour each day playing games on a console or hand-held device (Powers et al., 2013).

Over decades game-based learning has been debated. The earliest efforts of combining education and computer games can be traced to the 1960s and 1970s. Experimental work on computer-assisted instructions evolved into games and simulations. The possible motivational factor of using computer-based games for educational purposes was built upon (Games & Squire, 2006).

One early example is *PLATO*, a computer-assisted instruction system, developed at the University of Illinois, which allowed gaming interactions with multiple users. In 1972 the Carleton College in Minnesota developed *Oregon Trail*, a game explaining the history of American pioneers' lives during the 19th century. It was one of the first educational games that was used in schools. Originally text-based the game was later extended with graphics and sound.

There were several other attempts during the same time, such as *Logo*, a programming language for children engaging them in mathematics and programming, or micro worlds - self-contained computer-generated interactive worlds designed to model complex systems (Games & Squire, 2006).

With the emergence of video game consoles and personal computers multiple educational games were developed. Soon the effectiveness of connecting in-game rewards to in-game actions was recognized. Moreover, the use of challenges, goals and feedback that allowed users to enter a flow-like state was analysed. The concept of flow has since then been adopted and focused on, as described in section 2.4. The goal is to balance game difficulty and player's skills in a way to optimally engage players (Games & Squire, 2006).

In the 1980s to 1990s theories of motivation in education were developed. Amateur game developers emerged during this time, multiplying the amount of games available. Simulation games were a genre closely related to education as players were placed in as authentic and realistic environments as possible where they had to use history, geography or political knowledge to succeed. Popular games like *Pirates!* or *Civilization* paved the way for educational entertainment games in the early 1990s. Real-time 3D simulations, networked communications, player-generated content, computer-supported collaborative learning became interesting (Games & Squire, 2006).

Training games by the U.S. military brought the focus back to learning video games with the successful serious game *America's Army3*[1], and games developed by Universities at the beginning of the 2000s (Games & Squire, 2006). *America's Army3* was developed in 2002 by the Naval Postgraduate School on behalf of the United States Army. It is a first-person tactical shooter game trying to give insides into the work of soldiers and thus raise interest in young people planning their careers. The game is also used for training purposes and played by people around the world (Zyda, 2005).

With the emergence of countless video games there was a separation between entertainment and academic demand in educational games (Games & Squire, 2006). Some serious games emerged such as *CYBERCIEGE*[2] teaching people about cyber security to protect a fictional network (Greitzer et al., 2007), or *Prog and Play* teaching students programming (Muratet et al., 2009). From each game

[1]America's Army3: http://aa3.americasarmy.com/
[2]Cyberciege: http://cisr.nps.edu/cyberciege/

developed and analysed new findings emerge that can be realized in new prototypes or games which help the serious game industry evolve. *CYBERCIEGE*, for example, had different levels of difficulty to keep the learner interested and challenged, which tested positive, and analyses, moreover, recognized that individual feedback was helpful. This feedback is still interesting and applicable today.

Today there is a big industry in serious gaming, such as *game developers conference*[3]), *serious games association*[4], *serious games institute*[5], *serious games interactive*[6] to just name a few top ranked in the Google search engine.
Still researchers try to analyse the worth and benefits of digital games for educational purposes. There is a need to connect the game development branch and educators to create meaningful learning games. There are several events where these communities meet, such as *Games + Learning + Society*[7], *Games for Change*[8], *Games for Health*[9], or *Meaningful Play Conferences*[10] (Games & Squire, 2006).

Ideas and lessons learned from educational games developed over time can contribute when designing games with educational purpose today. The following section discusses objectives for the development of educational games.

### 2.4.3. Objectives for the Development of Educational Games

To develop an efficient learning game, learning objectives and contents should be integrated in the gaming missions and scenarios. Simply applying an educational background to a digital game is, nonetheless, not sufficient for producing these outcomes (N.-S. Chen & Hwang, 2014). Academic content should be integrated in the game-play not just added to the fantasy context of the game (Ronimus et al., 2014; Ke & Abras, 2013). Linking the enjoyment of the game to the learning process is key to a good educational game (Iten & Petko, 2014). The key to creating effective educational digital games is to implement appropriate

[3]Game Developers Conference: http://www.gdconf.com/conference/sgs.htm
[4]Serious Games Association: http://www.seriousgamesassociation.com/
[5]Serious Games Institute: http://www.seriousgamesinstitute.co.uk/
[6]Serious Games Interactive: http://www.seriousgamesinstitute.co.uk/
[7]Games + Learning + Society: www.glsconference.org
[8]Games for Change: www.gamesforchange.org
[9]Games for Health: www.gamesforhealth.org
[10]Meaningful Play Conferences: meaningfulplay.msu.edu

learning strategies, knowledge construction tools and educational theories (N.-S. Chen & Hwang, 2014).

Six factors contribute to the effectiveness of computer-based gaming: active participation, immediate feedback, dynamic interaction, competition, novelty, and goal direction (Tobias, J. Fletcher, et al., 2006).
In addition to the story, the design and implementational details, such as the game logic, database connection, networking, Artificial Intelligence (AI) are important to the success of a serious game. Educationalists have to work together with developers to create an innovative learning game (Greitzer et al., 2007).

Personal preferences in learning styles should also be considered when developing a learning game (N.-S. Chen & Hwang, 2014). As discussed in section 2.1, there are some guidelines to student motivation. Students have to be able to link new knowledge to existing experiences and see the relevance of the information for their every-day-life. Information should, moreover, be delivered in small chunks and the complexity should rise gradually. The narrow path between challenging and overwhelming the student should also be considered carefully (Greitzer et al., 2007).

Summing up, games with educational purpose should be designed with emphasis to the underlying learning principles, as well as the technical objectives of a gaming environment.
An important concept and learning technique that is often neglected in educational games is the social component and collaboration. While chats and instant messengers are used for this purpose, a novel approach is to integrate communication into an educational game in order to provide the student with an environment to explore, as well as a means of collaboration. Such a gaming environment can, for example, be implemented in a virtual world, as described in the following section.

## 2.5. Virtual Worlds

The last sections listed some objectives and characteristics of digital learning games. As the following section will show, virtual worlds are ideally suited to be used for learning games due to their properties.

### 2.5.1. Terms and Definitions

VWs, also known as immersive environments (Kuznik, 2009), are *"persistent virtual environments allowing large numbers of users, who are represented by avatars, to interact in real-time over a computer network such as the Internet"*, according to the definition of OECD (2011). Corbit et al. (2011) define virtual worlds similarly as *"online 3-D multi-user, avatar-based systems that support the creation of user-generated content"*. Bell (2008) takes into account several definitions that describe the basic characteristics of virtual worlds, the technology needed to create such worlds and the ideas of persistence and synchronous communication and combines them to the definition of virtual worlds as *"a synchronous, persistent network of people, represented as avatars,facilitated by networked computers"* (Bell, 2008). The various terms of this definition are described a follows (Bell, 2008):

- **synchronous:** In order to allow shared or coordinated activities a feeling of "common time" has to exist. Virtual worlds *"offer an awareness of space, distance and co-existence of other participants found in real life spaces giving a sense of environment"* (Bell, 2008), geography and terrain.
- **persistent:** Virtual worlds cannot be paused but continue to exist even after a participant left the world, opposed to common video games. Thus, the participant is a member of a dynamic community in a system that exists with or without him/her.
- **network of people:** Participants interact and communicate with each other in the environment affecting other participants in the system.
- **represented as avatars:** *"An avatar is any digital representation (graphical or textual), beyond a simple label or name, that has agency (an ability to perform actions) and is controlled by a human agent in real time"* (Bell, 2008). Hence, all actions and command given by the user are performed by his/her graphical character, the avatar. Avatars can be people, animals, creatures, monsters and others (Kuznik, 2009).
- **facilitated by networked computers:** In virtual worlds data and communication are facilitated through networked computers. These allow data management of all objects, environments, interactions and transactions, instant communication across national and geographical boundaries as well as storing them indefinitely.

According to Bell (2008) all these terms must apply in order to be a virtual world. As they are digital and networked (Corbit et al., 2011) they can be accessed 24 hours a day, 7 days a week in real-time. Users get the feeling of

being there with others and being able to interact with them (Kuznik, 2009). More general set of characteristics were summarized by Choi & Baek (2011) from previous studies. According to their research, characteristics of virtual worlds include persistence, representation (through, for example, avatars), numerous users, real-time interaction, shared space and social aspects such as interaction, community, chats, among others. Some studies address virtual 3D worlds rather than virtual worlds in general. 3D functionality can be seen as additional feature that two-dimensional worlds do not have (Choi & Baek, 2011; Berger, 2012). These definitions of virtual worlds include all kinds of games, most popular among them Massively Multiplayer Online Games (MMOGs) (Technopedia, 2015b). They fulfil all the criteria of the above defined term "virtual world", being a persistent, synchronous online platform where multiple users can meet in form of avatars and interact with each other or the environment. Moreover, they are hugely successful. The massively multi-player online games market, for example, generates 11 billion US Dollars in annual revenues in 2015. With that it represents about 21% of the digital game market (Superdata, 2015). There are several types of MMOs, such as Massively Multiplayer Online Role-Playing Games (MMORPGs) - focusing on the role-play (Technopedia, 2015c), Massively Multiplayer Online First Person Shooter Games (MMOFPSGs) - played from the perspective of the protagonist carrying a weapon (Technopedia, 2015a) or Massively Multiplayer Online Real-Time Strategy Games (MMORTSGs) - centring around building units with resources to defeat the opponent (Technopedia, 2015d), among others. Popular MMORGs include World of Warcraft (WoW) [11] with 100 million registered users or Dungeon Fighter Online [12] with 400 million registered users (Altay, 2015). There are also simulations or casual games which count as MMOGs, such as sports, racing or flight simulations. Casual MMOGs are of smaller time commitment and appeal to all computer users, including music, social or combat games. One famous example of a casual social game is Second Life [13].
The focus of these games lies in entertainment. The lines between gaming worlds and virtual worlds used for other purposes are, however, blurring (De Freitas, 2008).

There was a big hype about virtual world platforms between 2003 to 2008 (De Freitas, 2008) but interest has stagnated after that (OECD, 2011). Literature

[11] World of Warcraft: https://us.battle.net/account/creation/wow/signup/
[12] Dungeon Fighter Online: http://www.dfoneople.com/landing
[13] Second Life: http://secondlife.com/

agrees that virtual worlds were no longer of interest and, therefore, located in the "Trough of Disillusionment" of Gartner's Hype Cycle (Steinert & Leifer, 2010), which indicates the adoption of technologies, between 2010 and 2012. Since then they moved up the "Slope of Enlightenment" and are predicted to reach the "Plateau of Productivity" in 5 to 10 years (McDonald et al., 2014; Gregory et al., 2015). Other sources agree there has again been an increased number of development of virtual world in recent years (Wasko et al., 2011; Dawley & Dede, 2014). There has been, moreover, an increase in the use of virtual worlds as learning environments in recent years (Dawley & Dede, 2014; Duncan et al., 2012).

Summing up, virtual worlds need to meet certain criteria, such as a synchronous, persistent network of people, represented as avatars,facilitated by networked computers (Bell, 2008). In this thesis, the focus of virtual worlds lies on the use for educational purposes, as described in following section.

### 2.5.2. Learning in Virtual Worlds

Virtual worlds (VW) have great potential for learning and teaching practises (Kuznik, 2009). There are multiple advantages over other teaching strategies such as

- reaching a wider public, as it can be played all over the world (Kuznik, 2009),
- face-to-face interaction with students and educators around the world (OECD, 2011),
- overcoming geographic constraints as there are no national or cultural boundaries (OECD, 2011),
- richer and more dynamic social interaction and collaboration (OECD, 2011)
- creating a collective experience and collaboration, as virtual worlds can be used as multi-player environments,
- no constraints concerning the content, as basically every subject and material can be covered in a VW,
- being an opportunity for interactive activities that might not be possible in real life scenarios (Kuznik, 2009),
- offering access to resources and knowledge (OECD, 2011),

- providing examination of abstract and complex models through 3D visualisation or projections of visual information (OECD, 2011),
- enabling students to explore the subject, learn-by-doing and from a different perspective, and
- being an informal learning environment which allow a flow experience (Kuznik, 2009),

Moreover, virtual worlds have no age restriction, as children as well as adults can explore and learn with educational games. Although VWs for children, youth and adults differ in content, they offer learning activities and thus a safe yet motivating learning environment.
The success of educational scenarios in virtual worlds depends on effective design, delivery, and assessment (Moschini, 2010). Last of which can be done by logging the user's activities. This assessed information can then be analysed and used to support the learning player (Corbit et al., 2011). However, assessments can usually be done easily by game developers but not by teachers. Thus, making artefacts of learning more accessible to teachers is a goal for future learning worlds, according to Corbit et al. (2011). To ensure a stable virtual world learning environment, Calongne (2008) acknowledged that designers, instructors, and IT professionals are challenged to create stimulating content and to deliver it reliably. User interface and navigation is important, as well as the graphics that are chosen to enhance the learning environment. Gigliotti (1995) confirmed that interface, content, perception, plasticity and performance are the key factors to create an aesthetic and motivational virtual world.

#### Exploratory Learning

They enable users to explore the world "hands-on" even if it would be too difficult or dangerous in real life (Kuznik, 2009). Thus, virtual worlds are ideally suited to explore a subject of interest. OECD (2011) agrees that *"Virtual worlds can thus make learning easier, safer and more cost efficient than via textbooks and science labs."* The exploratory learning concept urges learners to explore and experiment to find a path of learning that feels natural to the learner. Only then he or she can come to conclusions and learn lessons (Rieber, 2005).

#### Collaborative learning

Berger (2012) stated that virtual worlds can be used as a tool for group-based learning and collaborative problem solving. Moschini (2010), explains that *"com-*

*munication and social interaction are at the centre of virtual world social experience. Virtual worlds therefore present an ideal platform for the engagement of learners in constructivist-focused educational practice."* Collaborative virtual worlds follow the same line of thinking by actively engaging their participants in learning activities and providing numerous possibilities to collaborate and socialise (Bonwell & Eison, 1991). Virtual worlds offer opportunities for visualisation, simulation, enhanced social networks, and shared learning experiences (Moschini, 2010).

### Problem-based learning

According to De Freitas (2008) virtual worlds can support many scenarios incorporating games or challenge-based learning where students can control their progress through exploratory learning experiences. As the user is able to make choices on his or her own, and achieve personal learning goals within the environment, virtual worlds lead to greater motivation (Lucia et al., 2009; Gütl, 2011). In addition to active participation, game-based approaches can be used to increase the intrinsic motivation of a participant (Garris et al., 2002). According to K. Miller (2015) it is important to learn through a process of experimentation, trial and error, without fear of failure. Students can explore a scenario that they would not be able to in real life due to geographic, political or content-related boundaries.

### Game-based learning

As discussed in section 2.4.1 digital game-based approaches are more motivating than purely computer-based learning approaches. The "game" element, therefore, is key factor to student motivation and engagement in a learning context (Moos & Marroquin, 2010). It is not enough to combine learning context and pedagogical methods in a virtual world but learning should be motivational, fun and story-based, according to Kasvi (1997). Therefore, game-based learning is included into the list of learning concepts for virtual worlds.
By involving the student in a story, creating a role-playing environment where he/she has to participate to see the story evolve, preparing challenges in order for the student to stay motivated and not get bored and allowing him/her to try things and fail without embarrassment but a chance to try again is along the lines what Kasvi (1997) is trying to convey with his rules for virtual learning. Key elements for him are people remember best when emotions are

evoked and they have a corresponding experience to what they learn. Therefore, while it is important to integrate pedagogical concepts, such as exploratory, collaborational and problem-based learning into a virtual learning world, the motivational "fun factor" should not be underestimated. While the learning world does not have to be a real game with all its components and rules, integrating a story that evolves around the subject to learn, gamification elements, or a game-based approach is advisable to create an interesting experience for the learner.

### Immersion

A great advantage of virtual worlds over traditional learning environments is the increased perception of immersion (Wasko et al., 2011) and presence, which describes the users' feeling of being in the real setting (Gibson, 2010; Slater, 2009). Although the two concepts are closely related there are some differences, for instance Dalgarno & Mark (2010) define immersion as a measurable characteristic of the world, dependent on technical capabilities to render sensory stimuli, whereas they argue, presence is the subjective reaction of an individual to immersion. Hence, different people can experience a different level of presence but the property of immersion is the same. The level of immersion influences the acceptance of and increased motivation and commitment in a virtual world (J. F. Chen et al., 2011). The more immersed a user is, according to (Reiners et al., 2014) the more the user may respond and adapt accordingly. The ability to focus in the world and the feeling of being there are important for successful engagement in virtual learning worlds (McDonald et al., 2014).

Based on this research the following learning methods can ideally be integrated in a virtual learning world.

### Challenges

Yet there are also challenges and limitations to learning in virtual worlds. Issues include policy challenges such as increasing requirements on broadband networks, lack of interoperability, standards between different worlds, increasing skill requirements for developers and end-users, as well as regulatory issues like increasing risk of online addiction, the increasing significance of in-world transactions for taxation, and classification and measurement issues.
One of the biggest challenges of using VWs for teaching purposes is to integrate them into traditional formal education settings as not every school or college

has the means and the teacher might not have the skills to use virtual worlds in their classrooms (OECD, 2011).
The ongoing debate on the risk of online addiction is already well known in the context of traditional web and other media usage. But the immersive character of the virtual reality environments increasingly blur the boundaries between real and virtual worlds. This may lead to users spending more time online, devoting more time to their virtual personality. Two psychological factors play an essential role in the increase of time investment and personal attachment in virtual worlds and especially MMOGs: *"the network of relationships that is accumulated over time; and the elaborate rewards cycle inherent in particular in MMORPGs"* (OECD, 2011). OECD (2011) quotes Yee (2002) emphasising *"[t]he anonymity and computer-mediated chat environment facilitates self-disclosure"*, which in turn also increases the social bonds. Yee also adds, *"[t]hese relationships can then be so strong, and many players have told personal issues or secrets to online friends that they have never told their real life friends or family."* The reward cycle works as incentives to stay alive in the virtual worlds are exponentially increased and intensify the emotional attachment (OECD, 2011). Due to the increasing importance of virtual worlds they become platforms for real economic transactions including transactions between users (consumer-to-consumer, C2C), as well as between users and companies (business-to-consumer, B2C). Users can create, sell and purchase virtual properties like land and objects. In order to cater this economic significance many real-life firms, such as IBM, Reuters, Telecom Italia and Toyota are active in virtual worlds, such as Second Life.

Summing up there are, on the one hand, great advantages to learning in virtual worlds that can not be matched by any other teaching method. On the other hand, there are still some issues and challenges when working with virtual worlds as technology-based learning is a new approach not distributed everywhere yet, and moreover there are new issues emerging due to the increased use of virtual worlds as teaching aid.
These articulations of how theoretical frameworks work with virtual learning worlds were considered during the development of this project.
Another issues to consider is which virtual world platform to use, which is discussed in the following section.

### 2.5.3. Virtual World Platforms

There are multiple different virtual world platforms which can be used to implement a virtual environment. In the scope of this thesis, the following two are considered: Open Wonderland (OWL)[14] and Unity[15].

OWL is built for educational and business contexts. OWL has its own advantages namely the modular style that creates expandability and the easy drag and drop functionality makes it user friendly to non-experienced computer users. There are other useful tools that OWL offers, including the built-in high-fidelity immersive audio capability that can be used for playback of audio tracks or communication between users, as well as the functionality of shared applications which allows shared editing of text documents. OWL, moreover, runs all kinds of applications, such as Firefox or Open Office, directly in-world (Foundation, 2015; Tomes, 2015).

Unity, on the other hand, has a robust graphics engine's platform diversity that allows Unity to detect the best variant for the current video hardware. Unity Technologies pride themselves on enabling cross-platform development for countless platforms, including PC (Windows, Mac, Linux/ Steam OS), consoles (PlayStation, Xbox, Nintendo, Wii), mobile devices (iOS, Android, Windows Phone, Blackberry) and websites (Maratou & Michalis, 2014). Unity can even be used for virtual reality (i.e. Oculus Rift, Gear VR and Playstation VR) and augmented reality (Unity3D, 2015b). Moreover, Unity is an intuitive and easier to grasp game engine for beginners than, for example Unreal Engine 4[16], uses mostly C# and JavaScript as programming languages which are very common, offers a huge asset store with free 3D models, has great graphics support for visual and audio effect, efficient rendering and physics engine and a detailed documentation (J. Marsh, 2014; Masters, 2015).
Unity's graphics and physics have very good quality compared to OWL and Unity allows the detection of the best variant of rendering specifications for the current video hardware which guarantees optimal hardware support. Unity also provides sharper 3D-objects, such as from the Unity Asset Store [17] or the 3D Google Warehouse [18].

[14]Open Wonderland: http://openwonderland.org/
[15]Unity: http://unity3d.com/
[16]Unreal Engine 4: https://www.unrealengine.com/
[17]Unity Asset Store: https://www.assetstore.unity3d.com/
[18]3D Warehouse: https://3dwarehouse.sketchup.com

Summing up, Unity is a good choice of game engine due to a robust graphics engine, interactiveness, possible cross-platform development, countless documentation and 3D objects.

### 2.5.4. Applications of Virtual Worlds as Learning Games

There are countless learning games in virtual worlds for different age groups, such as e.g. *SecondLife*[19] (adults), *Habbo*[20] (youth) and *Whyville*[21] (children). Kuznik (2009) researched lots of virtual world games and *"[..] some of them emphasize education (Whyville), while others focus on role play (Gaia[22]), fashion (Stardoll[23]), music (vSide[24]), sports, television, movies and books, toys and games from the real world (Barbie Girls[25]), casual games (Club Penguin[26]), socializing (Habbo), creating the content of the virtual world (Second Life)"* (Kuznik, 2009).

The most popular children game, launched in 1999 with 45 million users was *Neopets*[27], followed by *Poptropica*[28], launched in 2007 with 20 millions registered accounts and *Club Penguin* coming third, with 19 millions of registered users, launched in 2005. In the older age group *Habbo* with 100 million users, launched in 2000 leads before *Stardoll* with 21 million accounts, launched in 2005 and *IMVU*[29] with 20 million registered accounts, launched in 2004. Among adults the leading game is *Second Life* with 15 millions registered accounts, launched in 2003, followed by *Virtual MTV*[30] with 3 million users, launched in 2006 (Kuznik, 2009).

There are multiple subjects that can be taught in virtual worlds. For example, virtual worlds were used for virtual simulation for military, medicine and other sector training (De Freitas, 2008), as venues for role-play; for collaborative

[19]Second Life: http://secondlife.com/
[20]Habbo: https://www.habbo.com/
[21]Whyville: http://whyville.com/
[22]Gaia: https://www.gaiaonline.com/
[23]Stardoll: www.stardoll.com/
[24]vSide: http://www.vside.com/app/start
[25]Barbie Girls: http://games.barbiegirls.com/virtualworld/en/
[26]Club Penguin: www.clubpenguin.com/
[27]Neopets: http://www.neopets.com/
[28]Poptropica: www.poptropica.com/
[29]IMVU: www.imvu.com/
[30]Virtual MTV: http://mtv-s-virtual-world.software.informer.com/

building; to facilitate group work; as virtual class rooms; for various kinds of assessment; as a self-contained Learning Management System or for bringing geographically dispersed students/educators together facilitating interdisciplinary learning (McDonald et al., 2014). Many universities and educational institutions have a presence and run classes within *Second Life* to inspire learning; schools, in turn, use *Teen Second Life* for projects aimed at children (De Freitas, 2008). Ibáñez et al. (2011) used situated and collaborative leaning in a setting which resembled Madrid for foreign language learning, in order to immerse students and, thus, improve the learning results. Another example developed at a University is the *Technology Enabled Active Learning (TEAL)* environment that teaches physics (Pirker, 2013). There are countless examples of virtual learning worlds for different subjects.

### 2.5.5. Related Work Regarding Virtual Egyptian History Learning Games

In this project the focus lies on Egyptian learning worlds. In order to get design ideas and figure out potential problems when developing an Egyptian scenario, this section will take a closer look at several existing showcases of historic or Egyptian virtual worlds.

#### Giza 3D

The historic *Giza 3D* project of Harvard University aims at combining Giza archives, with numerous data of the Giza pyramids near Cairo, with a realistic 3D visualization of the site (Manuelian, 2013).

The Giza plateau west of Cairo is known for its large pyramids, as well as the famous Sphinx statue. There is endless documentation, photographs and drawings of the Giza pyramids and the surrounding site with tombs, temples and ancient artefacts. This data was collected and converted into electronic form by the Giza archive project[31], a collaboration of the Harvard University and Museum of Fine Arts, Boston (MFA) (Fine Arts Boston, 2015).

[31] http://www.gizapyramids.org

The Giza 3D project aims at combining these Giza archives with a realistic 3D visualization of the site, as shown in figures 2.3. The Giza pyramids can be explored virtually by students. *"The freedom to navigate through the Giza necropolis in real-time 3D, to observe it from any angle and in various stages of completion, offers novel possibilities for archaeological research"*, explains Manuelian (2013) and DassaultSystèmes (2013).
Due to the large amount of photographs from different eras of the site, the visualization allows going back and forth in time between them. Users can compare the look nowadays to when the site was still undamaged, as well as receive countless information about the buildings and artefacts, as shown in figure 2.4 and 2.5 (DassaultSystèmes, 2013).
Currently students can only explore the world alone and discuss the findings later in the classroom. An extension to the existing visualization is planned, introducing user avatars (Manuelian, 2013).

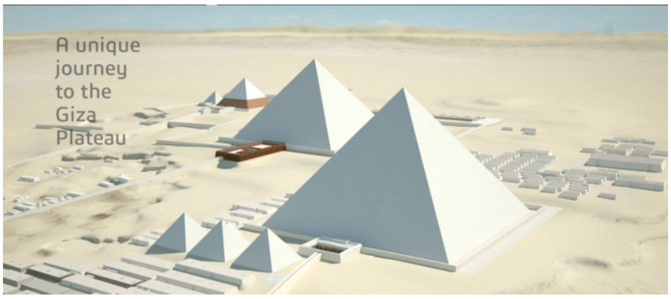


Figure 2.3.: Overview over *Giza 3D* visualization of pyramids of Giza (DassaultSystèmes, 2013)

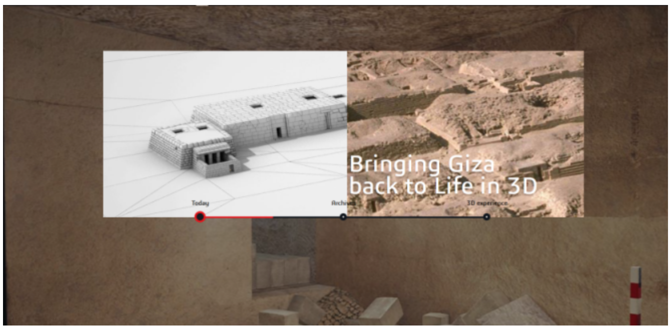


Figure 2.4.: Visualization of pyramids through photographs (DassaultSystèmes, 2013)

While this project has very valuable background and authentic visualizations, it lacks any gamified character, collaboration and challenges in the world, which

Figure 2.5.: Information about artefacts (DassaultSystèmes, 2013)

are requirements for this project.

### The Egypt Oracle

The Public VR is a "virtual" corporation, with a permanent board of directors and officers, but otherwise with no standing membership or staff but only contract-based partnerships with scholars and other affiliates around the world (PublicVR, 2015). They have several Egypt-based projects, such as *The Egypt Oracle*, the *Virtual Egypt Temple* and *Gates of Horus*.

The *Virtual Egyptian Temple* does not represent any particular site in Egypt but a sacred temple, the House of the Divinity embodying key elements like religion, government, daily life and harmony between heaven and earth (see figure 2.6 and 2.7). *"It is built from respected sources and intended to for all ages' curricula in history, archeology, religion, and culture"*, according to their website. There is a free 3D model accessible to the public, as well as tours of the virtual temple at the Carnegie Museum of Natural history in Pittsburgh (PublicVR, 2012d).

*Gates of Horus* is an educational game, based on the virtual Egyptian temple during which the player has question-and-answer dialogues with a virtual Egyptian priest regarding the temple's features and their meaning. Whenever the user gained enough knowledge in one part of the temple a gateway to another area opens. The aim is to reach the inner sanctuary and unlock the final mystery. The game works on a normal screen, as well as a "Corner Cave"

Figure 2.6.: Virtual Egyptian Temple (PublicVR, 2012d)

Figure 2.7.: Virtual Egyptian Temple (PublicVR, 2012d)

display, an arrangement where two projectors display on two screens at a 90-degree angle to create a unified panoramic view for the user (PublicVR, 2012b). It also works in a digital dome, a dome-shaped setup where the projection fills the whole interior of the dome (PublicVR, 2012a). See students playing the game in figure 2.8.

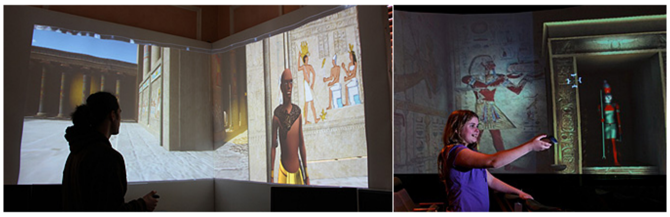

Figure 2.8.: Gates of Horus (PublicVR, 2012b)

The *Egypt Oracle* is a combination of virtual environments and physical experience (Jacobson & Gillam, 2012). It is an reenactment of an authentic public ceremony from ancient Egypt's Late Period. The virtual Egyptian temple is projected onto a wall in real-life scale. The audience navigates this 3D space during scene changes and plays the Egyptian population. There are several actors on-screen, as well as a costumed actor off-screen. The main character is a high priest, an avatar controlled by a live human puppeteer, hidden off-stage, as shown in figure 2.9. By combining the virtual reality with real actors an immersive and interactive experience is created. The show has a high level of historical accuracy, in order to show the audience how ceremony and drama were essential in ancient Egyptian culture (PublicVR, 2012c). The disadvantage is that the environment is not accessible to the public but only by attending live shows at a museum or university which organizes it. Broadcasts over the internet are a future goal, to at least make it watchable by people around the world (PublicVR, 2012c).

Figure 2.9.: Egypt Oracle (PublicVR, 2012c)

The temple and ceremony were modelled in Unity, which makes them similar to this project and a good reference for design and graphics. The challenging nature of the *Gates of Horus* are similar to the pyramid maze that is planned in this project. The fact that certain tasks have to be solved before moving on to the next chamber and level are incentives that might be interesting for this project.
What differentiates this project from the *Egypt Oracle* is the representation of the users in the world, which might improve the interactivity and immersion even more.

Another aspect interesting to this project is the representation in an 3D environment, such as the "Corner Cave", as this project's possible requirements include the 3D representation in a similar environment.

### Egyptian Scavenger Hunt

Tomes (2015) developed a virtual Egyptian learning world in Open Wonderland. Open Wonderland was chosen because it is freely available and easy to extend.

There were also several pre-defined tools available to integrate in the world.

The game-based world was is realized as a scavenger hunt. Egyptian artefacts with attached information pieces are hidden throughout the virtual environment (as shown in figure 2.10) and inside a pyramid constructed as a maze, that form a story once all of them are found. Information can be stored and then shared with others.
The game-based virtual world contains a set of learning tools that encourage exploratory and social learning. The area can be explored while the players have to communicate and collaborate to achieve the learning tasks (see figure 2.11. The modules include collaborative tools, such as a chat and a chatbot, and modules regarding the items, information gathering and a quiz about the gained knowledge.


Figure 2.10.: Egyptian artefacts can be found throughout the environment (Tomes, 2015)

Moreover, the learning tools are reusable, enabling teachers to create and maintain virtual learning scenarios.

An evaluation was conducted to get student opinions about the pedagocial approach. This resulted in general approval of the concept of the learning world and pedagocial methods, however, several issues were raised regarding the graphics, interaction and controls in the world.


Figure 2.11.: Multiple students meet in the world to achieve learning tasks collaboratively (Tomes, 2015)

### Other projects

There are several other projects, such as the rather old virtual tour of the *Fortress of Buhen* created in 1994. It consists of 3D models as well as a virtual tour. Virtual visitors who can look around in all directions are guided by a virtual tour guide describing what can be seen along the predefined way. See figures 2.12 and 2.13 for an impression of the original tour (LearningSites, 2015).

There has been much improvement in graphics since then, however, the tour lacks interaction and game-character for it to be of real relevance to this project.

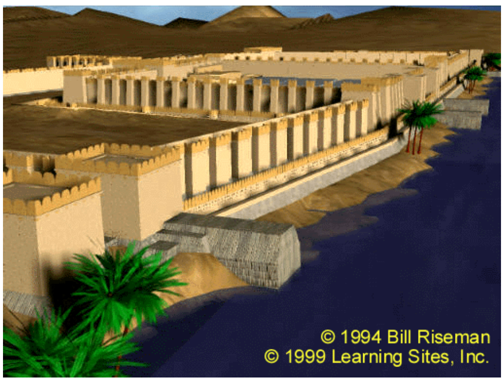


Figure 2.12.: Egypt Oracle


Figure 2.13.: Egypt Oracle

The National Museum of Scotland has several 2D games that teach about Egyptian culture and have interactive characteristics (Scotland, 2015). They have a lot of gamification aspects in the games which might be interesting to this project. However, they are no virtual learning worlds, therefore, again not particularly relevant to this project.

## 2.6. Summary

In this chapter it was established that motivation is one of the most important factors considering student learning. Therefore, knowing the reasons why students learn and what motivates them is essential. These reasons include usefulness for the students, qualification for later life, acceptance, consequences and curiosity, among others.
Another factor to consider is that there are different learning styles of students (visual, auditory and kinaesthetic, among others). As each student learns best in a different way, teaching methods have to be adapted accordingly, to gain best results with all students. After researching traditional, mostly passive (lecture, reading, demonstration), and more active teaching concepts (collaborative learning, problem-based learning, active participation) it was concluded and confirmed by literature that active learning methods result in better learning outcomes and motivation.
The current trend in teaching methods lies on technology-enhanced learning, such as serious games, edutainment games or digital game-based learning. In their way they all combine the entertainment of games with educational content, which looks like a combination with great possibilities. Studies, however, resulted in controversial outcomes regarding the beneficial nature of educational games on learning effectiveness. The effect of game-based learning on motivation was mostly positive. Therefore, educationalists and developers try to work on objectives for games with educational purpose that will increase the learning effectiveness. These include integrating learning contents in the gaming mission and scenario, hence linking the learning progress to the enjoyment of the game. Moreover, learning strategies and educational theories should be focused on and implemented.
Learning concepts that work well in virtual worlds were, moreover, discussed and it was found that collaborative, exploratory, and problem-based learning show potential, along with game-based learning. Immersion and challenges are

further key factors that should be considered when creating a virtual learning world.

In this project, therefore, the learning concepts collaborative learning, exploratory learning and challenge-based learning were incorporated into the game, as described in later sections.

# 3. Design, Requirements and Decisions

Chapter 2 established a common knowledge regarding student motivation, learning types and concepts, as well as educational games and the use of virtual worlds for game-based learning scenarios. This knowledge is now used to create a virtual learning environment that integrates learning concepts to best achieve motivation and learning effectiveness.

In this chapter, firstly, the onset situation is established, as this project is based on a previous project which is extended in the scope of this thesis. Lessons learned and issues raised from this first prototype, as well as the literature findings made in chapter 2 are combined to create a set of requirements for the improvement of said project throughout this chapter.
A requirement analysis collects design requirements and documents decisions made to realize this project. Aspects to be considered include the virtual world platform and network support, as well as, the integration of learning concepts and the learning modules to be implemented.
Moreover, this chapter finds objectives for re-creating and extending the previous learning world and describes the basic architecture of the modules included.

## 3.1. Requirements and Objectives

This section will collect requirements and formulate objectives for the project.

### 3.1.1. Open Wonderland-Prototype Analysis

The project described in this thesis is an extension of a previous prototype that was developed in Open Wonderland (OWL) by Tomes (2015) as described in section 2.5.5. The goal of this previous version was to create a virtual world environment for exploratory and social learning in 3D virtual worlds. The aim was to develop a set of tools that can be reused in different scenarios and, therefore, enable teachers to create and maintain learning worlds without many skills. These tools were categorized in the following modules:

- Item
  The item-module consists of *Itemize!*, *Inventory* and *Student Manager*, which turns objects into items with information pieces, allows storing of those items and assigning roles to the students.
- Quiz
  The quiz-module allows teachers to create quizzes and students to take the quiz after finding all the items.
- Itemboard
  The itemboard-module is the extension of an existing feature of OWL. Students can use the board to put up their gathered information and, thus, share it with the others.

As a showcase of this first prototype an Egypt virtual world scenario was implemented in OWL. Students can choose an avatar and username when logging into the world. The centrepiece of the scenario is a pyramid with several levels containing a maze where the items are hidden. In front of the pyramid the chatbot in form of a person is located. A truck represents the quiz. There are teacher menus for creating items and quizzes, along with a chat for students, among other context menus.

Tomes (2015) evaluation revealed general approval of virtual worlds for learning purposes, the learning concepts integrated and the learning modules in particular. Participants generally enjoyed the experience of exploring the Egyptian scenario and finding the items to form a story. The collaborative aspect appealed to everyone.
However, a number of flaws in graphics, controls and interactivities in the world came to light in the evaluation. This led to the decision of a follow-up project developed in Unity. The following issues were raised:

- Old-fashioned graphics

- Clumsy controls and navigation (especially in the pyramid maze)
- Not enough interaction with picked up items
- Not engaging/rewarding enough
- Itemboard has no intuitive controls, limited space and is not working as expected

The goal of this follow-up project is to extent and improve this first prototype. Likewise, the scope is to create a virtual world with educational purpose where students and interested people from all over the world can meet and learn together in the virtual learning environment. They can perform relatively simple learning tasks in an authentic yet safe environment which they can explore freely without having to be physically present. Still, they can benefit from the collaboration and social interaction as they would in an actual classroom, which is the core benefit of virtual learning environments over traditional e-learning systems.

The implemented modules (adapted from Tomes (2015)) include a set of different tools that support the learning in the world. The main purpose of the game-based world is knowledge acquisition from various informational objects. Students then have the means to store it. Upon finding all information a quiz should test the student's knowledge memorization on the new topic. There are challenging and collaborative tools supporting students in achieving the learning tasks. An overview over all modules and tools is given in section **??** and a more detailed description and screen shots of the virtual world in chapter 5.
Learning concepts and teaching methods are integrated in the virtual world to gain best possible learning outcomes. A discussion of the implementation of exploratory, collaborative, challenge-based and game-based approaches can be found in chapter 5.

The "Egyptian scavenger hunt" showcase is revisited, however the world is implemented in Unity instead of OWL as game engine, to overcome platform-related issues. The issues arising from Tomes (2015) feedback are considered in the re-design and development of the new world in Unity. Moreover, adaptations concerning the collaborative tools and challenging nature of the game-based virtual world, regarding the issues listed above, are made, as described in later sections.

Ensuring flexibility, in order for teachers and educators to edit and maintain the world, is of importance. The modules and tools developed should be extendible and reusable in different scenarios.

An evaluation of the adaptations made to the tools and the improved learning environment in Unity can be found in chapter 6 and gives useful comparison of OWL and Unity as game platforms for the implementation of virtual learning worlds.

Summing up, the following objectives can be concluded from the onset situation regarding the previous prototype:

- Create a learning environment for exploratory and collaborative learning in 3D virtual worlds.
- The created virtual environment including a set of learning tools should be implemented in Unity.
- Facilitate flexibility in order to enable teachers to create and maintain a world.
- The learning tools should be reusable in different scenarios.
- Improve and extent the first prototype to overcome issues raised.
- Revisit the Egyptian "scavenger hunt" scenario to showcase the implemented tools.
- Evaluate the new Unity prototype accordingly regarding motivation, immersion and usability of the world, and compare it to the first prototype implemented in OWL.

### 3.1.2. Requirement Analysis

From the literature research several requirements regarding virtual worlds, learning in virtual environments and learning concepts used to improved them, can be determined. The analysis of the first prototype provides requirements regarding the learning modules and learning concepts integrated. This section will collect and discuss these requirements.

Considering the requirements of this virtual learning world two main stakeholders have to be considered: (1) instructors, and (2) students. Instructors require a user-friendly environment they can easily create or maintain by adding, editing or deleting learning content in form of items or quizzes, assigning usern roles and analyse used behaviour by viewing the log files of each student. Students need an environment that motivates them to engage in the learning tasks. As discussed in section 2.4.1 game-based learning can be motivational for student engagement and interest in the subject. Therefore, measures have to be taken to promote motivation in the virtual world. This can be achieved by creating an interesting, challenging story that captivates the player and an environment that can be explored, on the one hand. On the other hand, design and implementation of the game-based virtual world are of key importance, including the game logic, database connection and networking. Moreover, in order to produce a game-based virtual world, a multi-user virtual environment is needed. This, in turn, calls for a server-client-based networked architecture. Therefore, a virtual world platform is required that allows multiple users to meet in a single world via a network.

Simply applying educational background to a digital game is not sufficient to produce good learning outcomes as pointed out throughout literature in chapter 2. The academic content should be part of the game-play not just added to the fantasy context, by integrating it in the game's missions and scenarios. Therefore, the main goal of this project is to implement suitable learning tools to be used in the virtual learning environment developed in the virtual world platform. These tools should then be reusable in any world that is created by the platform of choice.

Also shown in literature is the importance of active participation and dynamic interaction, as well as challenges and collaboration. Objects in the world should be interactive. The player should have a choice in handling objects and choosing a way to achieve the learning goal, make decisions that affect the learning outcome and, therefore, allow individual learning to a certain extend.
Rewards, challenges and feedback could be integrated and the environment might be enhanced by game-based approaches such as different colors for tasks already done or progress indicators, to increase motivation in and participation with the learning modules.

Therefore, the design should focus on the strengths of virtual worlds that set them apart from conventional e-learning tools, emphasising the interactive, exploratory and collaborative elements. The overall requirements to the virtual learning world are:

- **Knowledge Acquisition through exploration**,
  An environment and subject that can be explored to acquire knowledge, as well as promote student motivation and engagement in the world.
- **Conceptual Understanding through Collaboration**, and
  Collaborative in-world tools, such as a chat or itemboard for sharing

and discussing their findings raises student motivation and conceptual understanding of the subject.

- **Measurement of the Learning Progress through Assessability**
  Students should be able to view their progress and measure their knowledge acquisition. This learning progress should also be assessable by the instructor.

## Functional Requirements

Regarding the learning modules implemented in the virtual world, following functional requirements can be outlined:

- Knowledge Acquisition through Exploration
- Enhancement of Conceptual Understanding through Collaboration
- Measurement of the Learning Progress through Assessability

**Requirements towards Knowledge Acquisition**
The aim of the game-based virtual world is to find items that are hidden somewhere in the virtual environment. The items have pieces of information attached and the player can find them in their own pace and then combine them to a story. Every player has an inventory containing the items he/she has already picked up. The "Item Module" is, therefore, composed of:

- informational items, and
- the inventory.

A general impression of the subject matter should be given by creating an exploratory environment representing the real environment. Authenticity and realism are important to enhance the understanding. Support the exploration of the environment and the subject as much as possible. In their quest to find the items students explore the area with the help of several tools, forming the "Exploratory Module":

- a begin statement/ storyline,
- hints,
- a map, and
- progress stars.

Moreover, a chatbot can be questioned for information. The following functional requirements were identified:

- Information acquisition by finding items with attached information pieces

  - Instructors should be able to add new items
  - Students should be able to pick up and store information from items (inventory), and talk to the chatbot
- Information acquisition by questioning the chatbot
  - Instructors should be able to add new information to the chatbot
  - Students should be able to question the chatbot
- Give a general impression of Egypt
  - Students should be able to explore the Egyptian environment
- Provide supporting tools and an introduction to promote understanding of the story
  - Students should be able to see the underlying story (begin statement), to understand the goal of the virtual learning world (hints) and to find their way around the world (map)

**Requirements towards Enhancement of Conceptual Understanding**
To really understand the acquired knowledge and subject matter, discussion and sharing of information should be promoted, as this leads to understanding of a subject. To moreover promote collaboration, not all information can be picked up by each students, as different roles are assigned which restrict them from picking up all items. There are, moreover, quiz questions the player has to answer correctly before being able to pick up certain items. These tools constitute the "Challenge-based Module."

- roles with restrictions, and
- pick-up questions.

To overcome these obstacles students have to work together to achieve their learning goal. For this purpose, the "Collaboration Module" was created, including:

- a text chat,
- a chatbot, and
- an itemboard.

The text chat is for communication among each other, whereas the chatbot - an automated answering system - reveals information using predefined questions and automated answers. The itemboard is a board for sharing pieces of information. These functional requirements could be identified:

- Collaboration and communication possibilities
  - Students should be able to use the textchat and itemboard to share their knowledge
  - Students should be encouraged to collaborate by assigning them roles with pick-up restrictions
  - Teachers should assign roles with pick-up restrictions to encourage collaboration
- Promote interaction with the subject
  - Students should be able to pick up the items with information and answer questions about them (pick-up questions) to revise their knowledge

**Requirements towards Measurement of the Learning Progress**
In order to measure and assess the learning progress a quiz is needed. An important module used after finding all the information pieces is, therefore, the "Quiz Module" which quizzes the players' retention of the learned information. Moreover, instructors should also be able to review the students actions in the world. The "Analytic Module" was added for teachers, to monitor the students behaviour in the virtual learning world. By logging the player's interaction with the tools in the virtual world and the other students, interesting conclusions can be drawn. Following simplified requirements for measurement of the learning progress can be identified:

- Memorize gathered information
  - Students should be able to review and memorize information of items they already picked up by having to answer pick-up questions
- Show the progress in the world
  - Students should be able to view their progress at any point (progress stars)
- Test the newly gained knowledge
  - Teachers should be able to add, edit and delete quiz questions
  - Students should be able to take the quiz
- Analyse the learning progress of students
  - Teachers should be able to review the students' behaviour in the learning world by analysing the log files produced by the logging system of the analytic module

## Non-Functional Requirements

To conclude, the project and its stakeholders have the following non-functional requirements, as adapted from Tomes (2015):

1. Extensibility, flexibility, availability, usability of the multi-player virtual world platform
2. Availability and scalability of the server-client network
3. Good graphics, usability and performance of the environment
4. Effectiveness and quality of the learning experience based on learning concepts

**Requirements towards the Virtual World Platform**
As defined in literature a virtual world is a synchronous, persistent network of people from all over the world, who are represented as avatars in the virtual environment. The requirements regarding the virtual world are, therefore, to be usable by multiple players at the same time, represented by avatars. This is necessary to ensure a social connections and collaboration between the users. Other important factors for developers are the extensibility and flexibility of the virtual world. Moreover, the usability of the game platform, the availability of existing resources and documentation of the platform is essential.

**Requirements towards the Server**
The server's duties include synchronisation and persistence over the network. The player's positions and other shared content, such as communication, has to be synchronized over the network. The server is, therefore, the central point between multiple clients and has to be accessible 24 hours a day, 7 days a week in real-time. As multiple users might be present in the world at the same time, the server has to be scalable without lacks in performance. The server capacity has to be designed so nobody experiences delays.

**Requirements towards the Environment**
The overall effect of the created environment is key to the experience of the player. Authenticity increases the motivation which in turn increases the engagement and learning effectiveness. Important aspects for the end-user include, therefore, a good graphical interface and easy usability. An authentic 3D user-interface leads to better immersion in the virtual world which in turn leads to more motivation and engagement.
Usability is also an important factor in video-games and virtual worlds. Only if the player wants to engage in the game-based world he/she will be motivated enough to take part in the learning tasks. The world has to be easy and intuitive

to handle and operate.
Response times and general performance should be good enough to ensure an uninterrupted learning experience.

**Requirements towards the Learning Experience**
As described before, integrating learning concepts in the game scenario instead of simply applying an educational background to the game, is a vital aspect of effective learning in educational games. Linking the enjoyment of the game with the learning progress by implementing appropriate learning strategies and knowledge construction tools is key to creating a successful learning game. Regarding the different learning concepts described in chapter 2, following are best suited for the use in virtual worlds are incorporated in this project: collaborative learning, exploratory learning and challenge-based learning.

*Collaborative Learning*
For collaborative learning social interactions in the world have to be possible. These can take the form of communication tools such as text or voice chat, or actively engaging the players in group activities. Moreover, immersion is an important part of virtual worlds and collaboration. Making the player feel that he/she is in the scene with others and belongs to a group, possibly by using avatars, is required. There are five ways to encourage collaborative learning: positive interdependence, promotive interaction, individual accountability, social skills and group processing. For this project it is assumed that the students have enough social skills to work collaboratively. The virtual learning environment should meet the remaining requirements, namely positive interdependence, promotive interaction, individual accountability and possibly group processing. A high degree of interaction and the possibility to collaborate with others, enhances the motivation of the player. Therefore, enabling communication and collaboration in the virtual world is one of the main requirements.

*Exploratory Learning*
The exploratory learning concept urges learners to explore and experiment to find the path of learning that feel natural to the individual learners. The learning world should, therefore, provide a safe, authentic environment for the player to explore a subject that he/she might not be possible to explore due to geographic, political or content-related boundaries.
By exploring the student might reach unexpected conclusions and higher-order thinking is promoted. The following aspects are listed as the main principles of exploratory learning:

- Learners control their own learning
- Knowledge is rich and multidimensional
- There are diverse ways to approach the learning task
- Learning feels natural and does not have to be enforced

Another requirement is, therefore, creating an authentic environment where exploratory learning is promoted.

*Challenge-based Learning*
Challenge-based learning can be used to increase motivation. Without the fear of failure the student can experiment and find his/her own solutions to challenges in the learning tasks. Challenge-based learning can be used in virtual worlds where students can control their own learning progress through exploratory learning experiences. It can, therefore, be combined with the other learning concepts above.

*Other learning Concepts*
There are other aspects that have proven beneficial to the learning effectiveness such as learning instructions, knowledge of correct response feedback and in-world rewards. These concepts might be integrated in the learning world.

As educational games convey a learning content in a game-based environment it should be as authentic and the tasks as realistic as possible. Therefore, making the learning tasks more fun by applying progress indicators, which are similar to in-world rewards, or color-codes for certain tasks might be beneficial to the students' motivation.

### 3.1.3. Objectives

The last two sections showed the onset situation of this project, another project implemented in OWL, and the objectives gained from analysing the outcomes and issues of this previous project, as well as the requirements collected from literature research on the subject learning in virtual worlds. This section will summarize these requirements and formulate objectives.

Included in this project is the requirement

- *to develop a set of learning tools in Unity*
  These tools should facilitate effective learning in the world and meet the above described functional requirements.

- *the learning tools should be universally applicable, thus, re-usable in any virtual learning environment*
  It is intended for these tools to be applicable to various learning scenarios. This should facilitate teachers to create and maintain learning worlds relatively uncomplicated and flexible.
- *to develop a virtual Egyptian environment in Unity*
  The "Egyptian Scavenger Hunt" scenario is to be revisited and implemented in Unity to demonstrate the implemented learning tools. The learning environment should meet the non-functional requirements, listed above.
- *to evaluate the learning tools and showcase environment*
  This learning world is then to be evaluated and compared to the results of Tomes (2015) outcomes.

Furthermore, three main pedagogical objectives were determined by Tomes (2015) and adopted for this thesis, for this virtual learning world: (1) knowledge acquisition, (2) enhancement of the conceptual understanding, (3) measurement of the learning progress. These objectives should be facilitated by the use of certain teaching methods implemented in the virtual learning environment, collaborative learning, exploratory learning, challenge-based and game-based learning. Several in-world learning modules and activities were implemented based on these pedagogical concepts.

In terms of technology used the objective was to use the game engine Unity, as discussed in section 3.2.1. This decision is based on the feedback gathered from the evaluation of Tomes (2015) learning environment which was carefully considered and analysed before adaptations and improvements were implemented in the Unity-based VW project. This extension of the original project is supposed to incorporate all original modules and tools (e.g. Chatbot) and look similar to the extent of using better graphics and improving the flaws. There were no other restrictions set on decisions regarding technical configurations.

An additional goal was to facilitate demonstrating the virtual world in a 3D environment, such as "Hub for Immersive Visualisation and eResearch" (HIVE) at the Curtin University. This was not possible with OpenWonderland but the idea is to make it work with Unity.

To sum up, a set of learning tools should be implemented to support knowledge acquisition, understanding of the subject and measurement of the progress. They should be reusable to add flexibility for teachers. The learning concepts of collaborative, exploratory and challenge-based learning should be integrated to facilitate best results in the learning world. An Egyptian scenario is to be implemented in Unity to demonstrate the learning tools created.

## 3.2. Technologies

Technologies to be considered in this project are the virtual world platform and the networking solution. Following sections discuss the choice of platform and networking.

### 3.2.1. Virtual World Platform

Using Unity was a prerequisite of this project due to the issues raise in the first prototype implemented in OWL.

Replicating the exact world might not be possible given the different game engines. This is attributed to the fact that OWL and Unity offer different pre-installed or add-on tools that facilitate the implementation of features. OWL provides ready-to-use solutions for text chat, voice chat, different kinds of panels and menus (property panel, error panel, context menu), user list, sticky note, as well as adaptable features, such as, a whiteboard and avatar creation that were used (Tomes, 2015).
Unity has no built-in tools, however is an easy to learn platform for beginners, uses a common scripting language, has a large selection of 3D models in the Unity asset store and countless tutorials and documentation. It is, moreover, know for creating projects with good graphics and interactiveness.

Summing up, Unity was the virtual world platform of choice for this project.

### 3.2.2. Networking

Unity offers a standard out-of-the-box networking solution, but there are also several other network solutions that are easily integrable into the Unity editor and offer simple networking. Unity 5.1 offers a new networking approach. This project, however, is implemented in Unity 4.6, therefore, following networking solutions were available, among others:

- Standard Networking Elements in Unity
- Forge Networking[1], uLink[2]
- Photon Bolt[3]
- Photon Unity Networking (PUN)[4]

The standard Unity networking offers a high level and lower level networking API, which support basic networking. There are multiple tutorials and it is easy to start. However, the general assumption in the Unity community is that the built-in networking is not suitable for real-world games. Peer-to-peer connection is not easy to handle and it is commonly not recommended for slightly advanced networking (Domagoj, 2011).

Solutions such as Forge networking or uLink are not available for free, which is the main reason it was not chosen for this project.

Photon Bolt stopped receiving regular updates and is generally not recommended in forums[5].

Photon Unity Networking (PUN) is a real-time multi-player game development framework which has server and cloud services. It is hosted in a globally distributed cloud to guarantee low-latency for players around the world. Advantages of PUN include:

- it is hosted on PUN's globally distributed Photon Cloud,
- the player who created the room can leave without causing crashes for the clients,
- it is stable,
- the source code is available to fix issues if necessary,
- it scales automatically and up to tens of thousands of users (free for under 20 users), and
- is easy to use (PhotonEngine, 2015).

[1]Forge Networking: https://www.assetstore.unity3d.com/en/content/38344
[2]uLink: developer.muchdifferent.com/unitypark/uLink/uLink
[3]Photon Bolt: https://www.photonengine.com/en/Bolt
[4]PUN: https://www.photonengine.com/en/PUN
[5]https://www.assetstore.unity3d.com/en/content/38344

A disadvantage might be that it is not a self-hosted server, therefore, the virtual world depends on an external server. A self-hosted server was considered briefly - Smart Fox Server (SFS)[6]. It was disregarded, however, as peer-to-peer connections created some problems, there are only string-parameters, and a simple, not self-hosted, out-of-the-box solution was preferred. PUN is very stable, flexible and scalable which is why Photon Unity Networking was chosen for this project.

To sum up, Photon Unity Networking was chosen as it is an easy to use networking solution, that offers a flexible, cloud-based service. It can be used in C# and there are multiple tutorials, which make it a good choice for beginners.

## 3.3. Architecture

The virtual world environment has a very simple architecture. It consists of a server-client structure, where students are clients, that are possibly located around the world. Once they start the virtual world they connect to the PUN-server, which makes synchronization and collaboration possible.

The project consists of the modules implemented in Unity. Except for the Photon Unity Networking, no external extension to the virtual world was used. Moreover, as Unity does not offer pre-defined modules for text chats or other aspects of this project, the modules were implemented from scratch.
Furthermore, no database was necessary. The only means of saving data to the user's computer is done by writing XML-files. Figure 3.1 shows the conceptual architecture of the project. The learning modules implemented in Unity consists of several tools each. Tools coloured in blue are student tools, those with red edges are student as well as teacher tools and only red signals a teacher tool. It is shown in a simplified way how the student and administrator use the modules. Moreover, it is demonstrated which tools read and/or write to XML files. Black arrows represent access from teachers and students, red means teacher-access only and blue student access-only. Furthermore, the tools which communicate with the PUN-server are indicated.

Figure 3.2 shows a round trip through the virtual world in form of a flow chart, from users logging in over the administrator assigning roles to students using

[6]SFS: www.smartfoxserver.com/

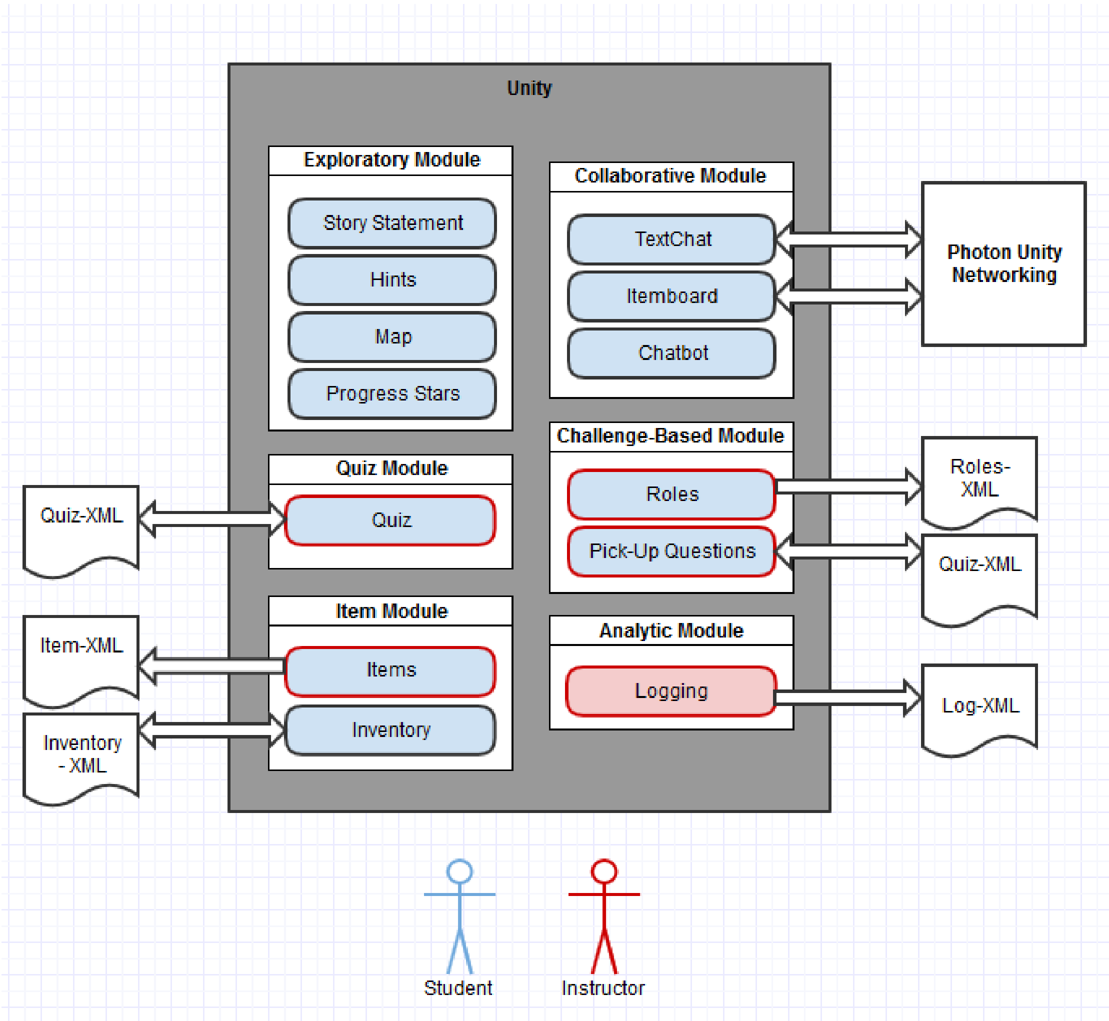


Figure 3.1.: Basic architecture of the virtual world including the learning modules, xml access and networking access. Blue tools are students tools and red tools for the instructor. Red rimmed tools can also be used by the instructor.

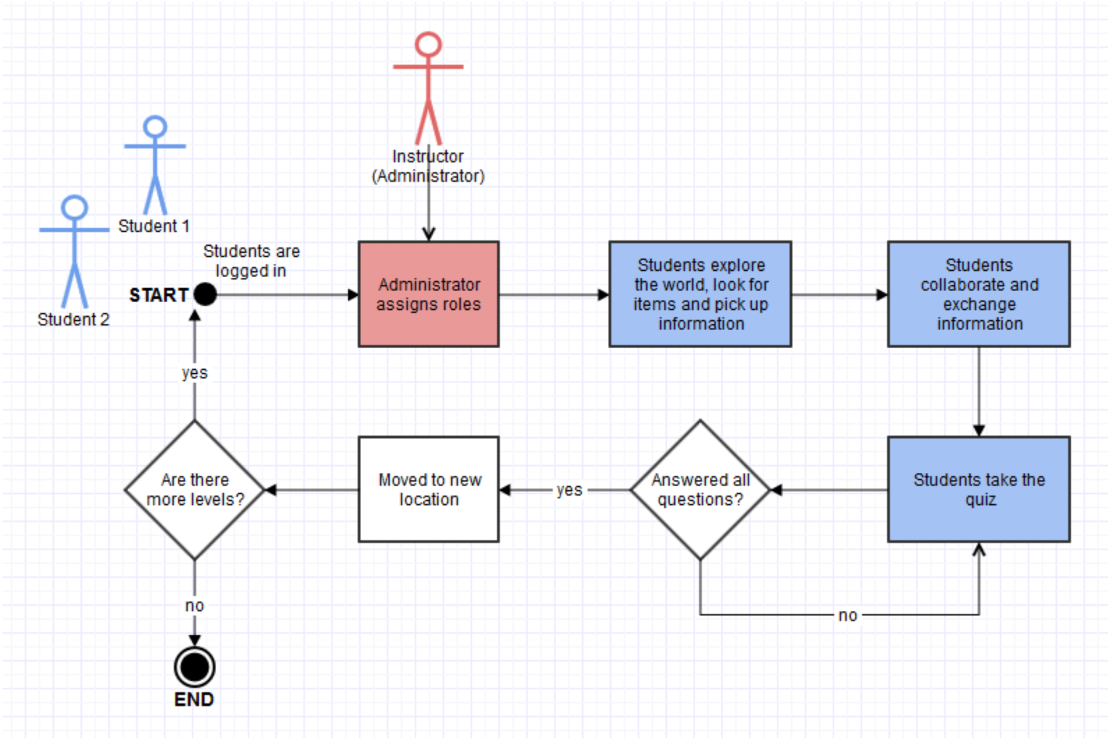


Figure 3.2.: Learning round trip through the virtual world as a flow chart

the virtual world (including finding items and collaborating), taking the quiz and finishing the learning trip. Subroutines (in this case scenes), processes, data input, and decisions are represented accordingly.

## 3.4. Summary

This chapter described all requirements and objectives to the learning world, as well as decisions made. The requirements were combined from analysis of Tomes (2015) work and literature research conducted.

In the scope of this project the learning tools adapted from Tomes (2015) have to be redesigned, improved and implemented in Unity instead of OWL. These tools should be applicable to multiple scenarios and, therefore, offer a certain flexibility for teachers to create and maintain learning worlds. The modules include the ″item module″, ″exploratory module″, ″challenge-based module″, ″quiz module″ and ″analytic module″.

The learning world should integrate important learning concepts, collaborative, exploratory and challenge-based learning. By using these learning approaches knowledge acquisition and real understanding of the subject should be facilitated.

An Egyptian-based scenario is to be implemented in Unity to demonstrate the learning tools and an evaluation of this implementation should show the improvements and the acceptance of the learning world and can be compared to outcomes of the previous prototype's evaluation.

# 4. Implementation

The focus of this chapter lies on the implementation of the modules described above, which were created to fulfil the requirements and goals of this project. Details of the implementation in Unity and the structure and connection of the different objects are discussed.

## 4.1. Programming Environment

In the course of this thesis Unity 4.6 was used, with C# as programming language. As a programming environment the Unity editor, as well as the supplemented MonoDevelop-editor for coding was used. External tools used include Photon Unity Networking (PUN), which was described in section 3.2.2 and is further discussed in 4.1.2. No other external modules were used.

### 4.1.1. Unity 3D

This section describes the Unity game engine and its components.

#### Unity Editor

The Unity editor consists of several windows: the main 3D scene window where objects can be placed, scaled and rotated, as well as the game view which shows a game preview, the project's directory structure, the hierarchy of objects in the scene and the *Inspector* - a properties panel to edit the the objects. The scene is assembled by various 3D objects, called game objects, which can have components, such as materials, sounds, physics properties or scripts. Simple game objects, such as light sources or primitive objects (cube, sphere, plane) can be created in the editor. More complex 3D objects (so called *Assets*), such as

2D or 3d objects, animations and sounds among others, can be downloaded from the Asset Store[1]. Scripts define the game logic, as described in the next section.

Unity itself, its core, is written in C/C++, so are all the graphics, sound and physics coding which is why it is so fast, smooth and performs well.

Section 4.2 describes the implementational details of this project, including the scenes, game objects and scripts implemented in the scope of this thesis.

## Technical Features

This section describes the most important technical features of Unity.

### Graphics

The scene of a virtual world is rendered by the graphics hardware, by so-called *Shaders* (Unity3D, 2015e). Unity's graphic engine is based on *DirectX 11*[2] (i.e. on Windows), *OpenGL*[3] (i.e. on Mac and Linux systems) and others, depending on the target platform (Unity3D, 2015h). Graphics include everything from lightening, cameras, shaders, particle systems, among others (Unity3D, 2015f).

### Physics

There are two separate physics engines for 2D and 3D (Unity3D, 2015a). All 3D physics calculations are handled by the *NVIDIA PhysX 3.3* engine[4]. This allows realistic behaviour in the virtual worlds, such as correct acceleration, collisions, effects of gravity and other forces. Physics can be controlled programmatically (Unity3D, 2015g).

### Animation

Characters can be animated by Unity's animation system *Mecanim*. It allows creating or importing animations for different body parts (Unity3D, 2015c).

[1] http://www.assetstore.unity3d.com/
[2] DirectX 11: https://msdn.microsoft.com/en-us/library/windows/desktop/ff476080
[3] OpenGL: https://www.opengl.org/
[4] Nvidia PhysX: https://developer.nvidia.com/gameworks-physx-overview

### Sounds

For music and sound play back Unity uses *FMOD*[5] sound effects engine, developed by the Firelight Technologies (Unity3D, 2015d).

### Scripting

Game objects can be expanded by scripts, which are neccessary to to create a game process and logic. Unity scripting is based on *Mono*[6], which is an open source, portable implementation of the .NET framework with a set of compatible tools, such as C# compiler, and a Common Language Runtime (Mono, 2015a). Mono enables Unity's cross-platform implementations on Windows, Linux distributions, OS X, Android, and even game consoles such as PlayStation 3, Wii or Xbox 360 (Mono, 2015b).
Unity supports the programming languages UnityScript (similar to JavaScript), Boo[7] and C#. The common scripting editor of Unity is *MonoDevelop*[8].

Assets and scripts can be combined to so called *Prefabs*, which are something like a template that can be reused if several instances of it are needed in the virtual world.

### Multi-Player Virtual Worlds

To implement multi-player worlds a client-server-structure is needed to synchronize important data over the network. The networking solution used in this project is described in the following section.

## 4.1.2. Photon Unity Networking

Photon Unity Networking (PUN) was already described in section 3.2.2. It is part of the Photon server engine. Photon is a real-time socket server and cross platform multi-player game development framework. Figure 4.1 shows the high level architecture of Photon. Photon Core is developed on C++ for performance reasons and supports reliable UDP, TCP, HTTP and web sockets. It is possible to

[5]FMOD: http://www.fmod.org/
[6]Mono project: http://www.mono-project.com/
[7]Boo: http://boo-lang.org/
[8]MonoDevelop: http://www.monodevelop.com/

communicate cross-platform and across protocols, as Photon handles everything like de-/serialization. The business logic contains the applications running on Photon and is written in C# or any other .NET language. The applications are on top of a development framework, that solves RPC calls and threading (Photon, 2015b). Load balancing adds a layer of scalability and is used to match players to a shared game session and send messages synchronously, in real-time between connected players across platforms (Photon, 2015a). This includes also Photon Unity Networking (PUN)which is Photon's Unity package for multi-player games. It provides authentication, matchmaking of the player to the game session, and reliable in-game communication through the Photon back end (Photon, 2015c).

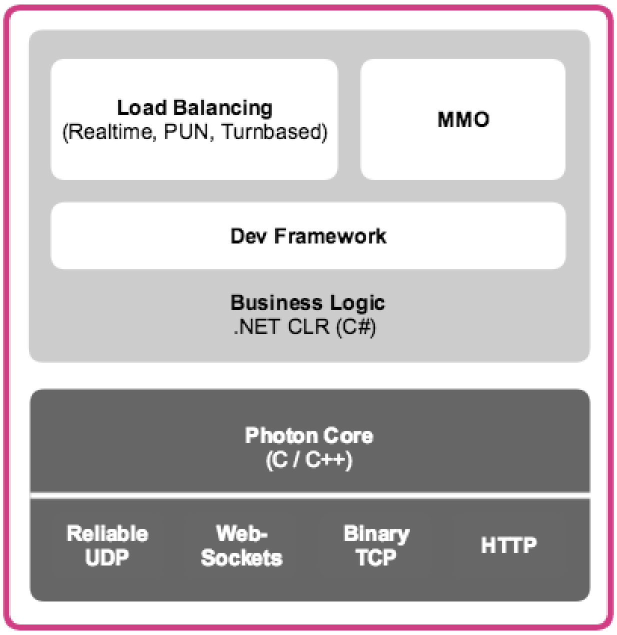


Figure 4.1.: Photon High Level Architecture (Photon, 2015b)

This section describes the networking implementation and integration in the project.

#### Photon Unity Networking installation

PUN can easily be integrated into Unity. The following steps have to be taken for installation:

1. Find PUN package on Asset Store.
2. Download the package.
3. Open the PUN Wizard (Window - Photon Unity Networking) and fill in email.
4. An email containing a link to the user account and the AppID will be sent.
5. This id has to be copied into the field "Your AppID", a region has to be chosen and saved.

After these installation steps PUN is successfully integrated into your Unity editor. In the Assets folder a "Photon Unity Networking" folder will appear.

#### How to use PUN

To use PUN a connection has to be established with the network, as seen in listing 4.1. This sets the client's game version. This is done in a `NetworkManager` script. The variable `PhotonNetwork.connected` informs about the status of the connection. The first player connecting to the network creates a room, where the other users join, as seen in listing 4.2. Due to PUN hosting the network the player who created the room can leave without causing crashes with the other players.

Listing 4.1: PUN connection to the network for a certain virtual world (Photon, 2015c)

```
PhotonNetwork.ConnectUsingSettings("v4.2");
```

Listing 4.2: Matching a player to a particular game by joining an existing room or creating a new one if player is the first to start the virtual world application (Photon, 2015c)

```
//Join room "someRoom"
PhotonNetwork.JoinRoom("someRoom");
//Fails if there are no open games.
//Error callback: OnPhotonJoinRoomFailed

//Tries to join any random game:
PhotonNetwork.JoinRandomRoom();
//Fails if there are no open games.
//Error callback: OnPhotonRandomJoinFailed

//Create this room.
PhotonNetwork.CreateRoom("MyMatch");
// Fails if "MyMatch" room already exists and calls:
//OnPhotonCreateGameFailed
```

Each game object that should be synchronized over the network has to have a `PhotonView` script attached. On this component a Remote Procedure Call (PRC)-method (marked with `PunRPC]`) can then be called which communicates with all players in the virtual world.

## 4.2. Implementational Details

In the following section the modules and tools and their implementation is described in more detail. Each section will have an overview over the game objects, scripts and possible XML-scripts used, following by a description of the implementation.

### 4.2.1. Game

This section describes the implementation of the general game elements and scenes.

#### Description

The game consists of four scenes:

1. start,
2. login,
3. game,
4. end scene.

In the start scene an introduction text is displayed conveying a quick overview over the story and the general idea what the student has to do in the game. A button leads to the login screen where the player can choose a username and avatar, or the administrator can login by clicking the administrator-toggle and then enter the correct username and password combination. By confirming the chosen information with the "login"-button the user enters the game scene, which is the main scene of the game. The game scene consists of the game environment, including the informational items, the chatbot, the itemboard and a menu, containing the map, chat, inventory, user information, hints and hotkeys. The end scene is reached upon finishing the final quiz after collecting all the items. There the player is no longer animated and only has the option to exit the game.

#### Implementation

Game Objects:

- GameController
- PrefabManager

Scripts:

- `NetworkManager.cs`
- `GameController.cs`
- `SpawnSpots.cs`
- `KeyManager.cs`
- `LoginConfigureAvatar.cs`
- `LoginAdmin.cs`
- `Music.cs`

| | |
|---|---|
| Left, right, front, back arrow | Walk |
| W, A, S, D | Walk |
| Left Shift | Run |
| Space | Jump |
| Esc | Exit Game |
| Tab | Exit Pyramid |
| C | Chat |
| M | Map |
| U | User information |
| I | Inventory |
| H | Hints |
| K | Hotkey Overview |
| R | Rotate or stop rotate view |

Table 4.1.: Key shortcuts

The start and login scenes consist of a canvas with a few UI elements, such as panel, text and buttons. The key script in the login scene is the `NetworkManager` script which establishes the connection to the network, creates or joins a room and loads the game level. The scripts `LoginConfigureAvatar` and `LoginAdmin` are helping scripts in the login process, for choosing the player avatar and confirming the administrator credentials, which are stored in a configuration file.
In the game level the `GameController` script is the first and central script is called. It spawns the player on one of several spawn spots in the game area and displays the correct menu canvas (for administrator or player). Under consideration of the administrator's configuration settings game parameters are set, such as if gamification stars are displayed, if pick up questions are asked and if the map is usable. The `KeyManager` script handles key shortcuts to several features, shown in table 4.1. The background music is started in the first scene and continues playing during the whole game. This is handled by the `Music` script containing the method `DontDestroyOnLoad()`.

### 4.2.2. Player

This section describes the implementation of the player.

### Description

The player is placed in the scene once the game scene has fully loaded. Each player experiences the game in a first-person view, as if actually seeing through the eyes of his/her avatar. The player can then see the avatars of the other users in the scene as well. For simplicity reasons only one male and one female avatar exist to choose from as avatar creation is not a pre-defined feature of Unity.

### Implementation

Game Objects:

- PlayerControllerFemale or PlayerControllerMale
- PlayerManager

Scripts:

- `PlayerMovement.cs`
- `NetworkCharacter.cs`
- `PlayerManager.cs`
- `Mouselook.cs`
- `MouselookCollider.cs`

The player game object consists of a

- Character Controller,
- Audio source,
- Animator,
- Mesh Renderer,
- `PhotonView` script,
- `NetworkCharacter` script,
- `PlayerMovement` script,
- `Logging` script,

and three child objects:

- the Camera and an AudioListener,
- the actual avatar body structure, and
- a TextMesh for the name tag above the avatars head.

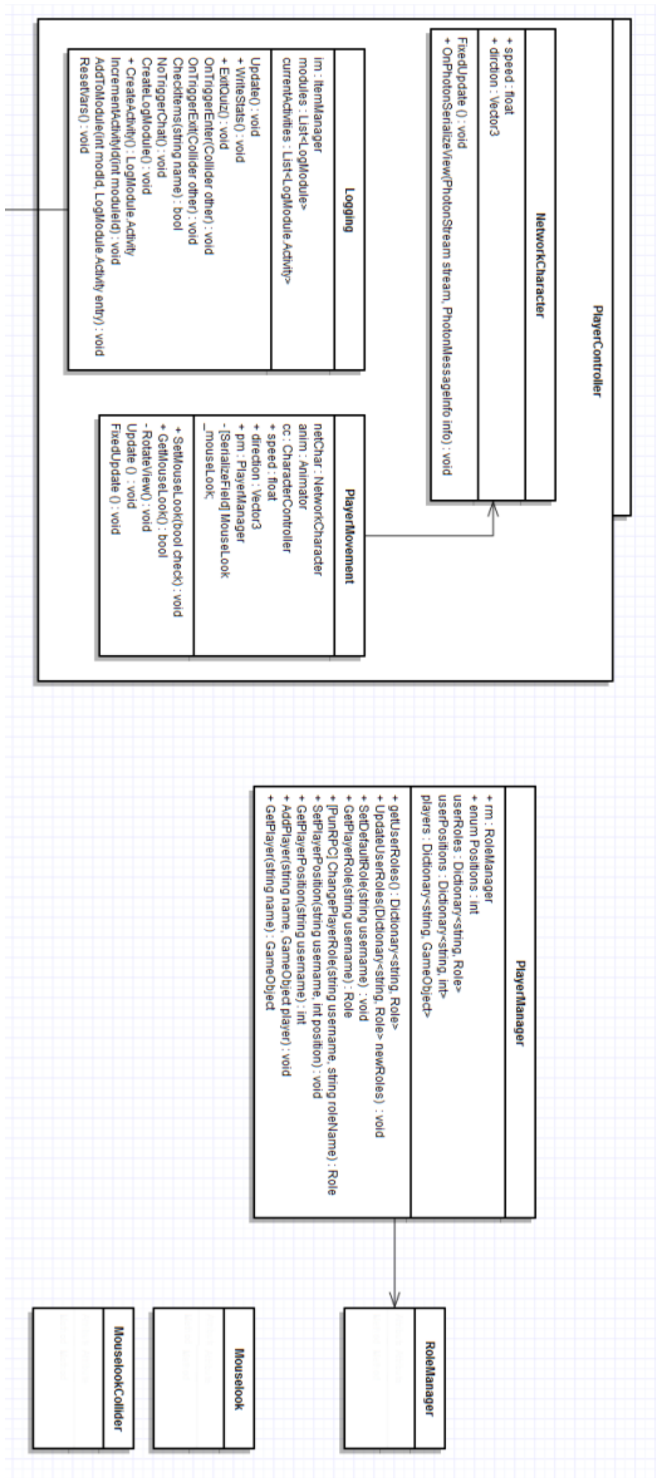


Figure 4.2.: Class diagram of the player elements

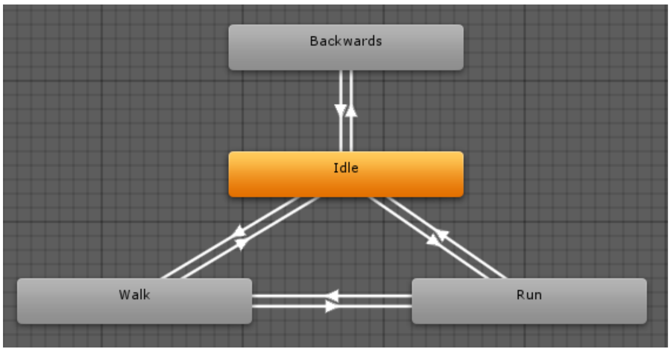


Figure 4.3.: Transitions between Idle, Walk, Run animations of player. If the threshold of 0 is exceeded the player changes from idle to walk and goes back to idle at 0 speed. If the left shift key is pressed down the player changes from walking to running and vice versa. If the back arrow is pressed, the player walks backwards.

Figure 4.2 shows the class structure of the player tool. The Character Controller is the collider of the person, handling collisions with other game objects. Animator is necessary for walk, run and idle animations of the player. The player is animated for an idle state or to either walk or run. The transition of these states is shown in figure 4.3. The audio source produces walking or running sounds. The `PlayerMovement` script reads the movement input and moves the player locally, whereas the `NetworkCharacter` script transmits the position, rotation and animation of the player over the network using the `PhotonView`. The `PlayerMovement` script and Camera are only active for the local player. The components are inactive upon instantiation and are activated for the local user by the `GameController` script. There is also a `PlayerManager` script which handles indirect player options such as role change, keeps track of the position of every player and has a Dictionary of all player game objects. The `Logging` script is discussed in more detail in section 4.2.9.

### 4.2.3. Network

All game objects that have to be synchronized over the network for all players to see, use the `PhotonView` component attached to their game object. These include the player (position and animation), the chat, the itemboard and administrator features (such as changing roles).

### 4.2.4. Item Module

This section discusses the implementation of the "Item"-module.

#### Description

Items with attached pieces of information are placed somewhere in the game environment. Once a player collides with an item the information panel appears and the item is picked up.

#### Implementation

Game Objects:

- items (currently: Osiris, Isis, Seth, Horus, Anubis, Was, Bastet, Apis, Alabaster Vase, Scales, Eye of Horus, Atef Crown, Sarcophagus, Ankh Symbol)

Scripts:

- `Item.cs`
- `ItemManager.cs`
- `ItemSerialization.cs`

XML:

- `items.xml`

Items are game objects with a collider and a halo attached. The collider is used for detecting the player's collisions. The halo is shining as long as the item is not yet picked up by the player. Upon pick-up the halo extinguishes to highlight those items still to be picked up. Moreover, items have two scripts attached. The `ItemInformation` script (described below) and the `ItemSerialization`, which handles reading item information from the XML-file and possible writing to the file. The item information in the file consists of an id, title, description and path to an image.

The `ItemManager` script is a helping script for creating items, returning certain items or the item count.
The class structure of the item tool can be seen in figure 4.4.

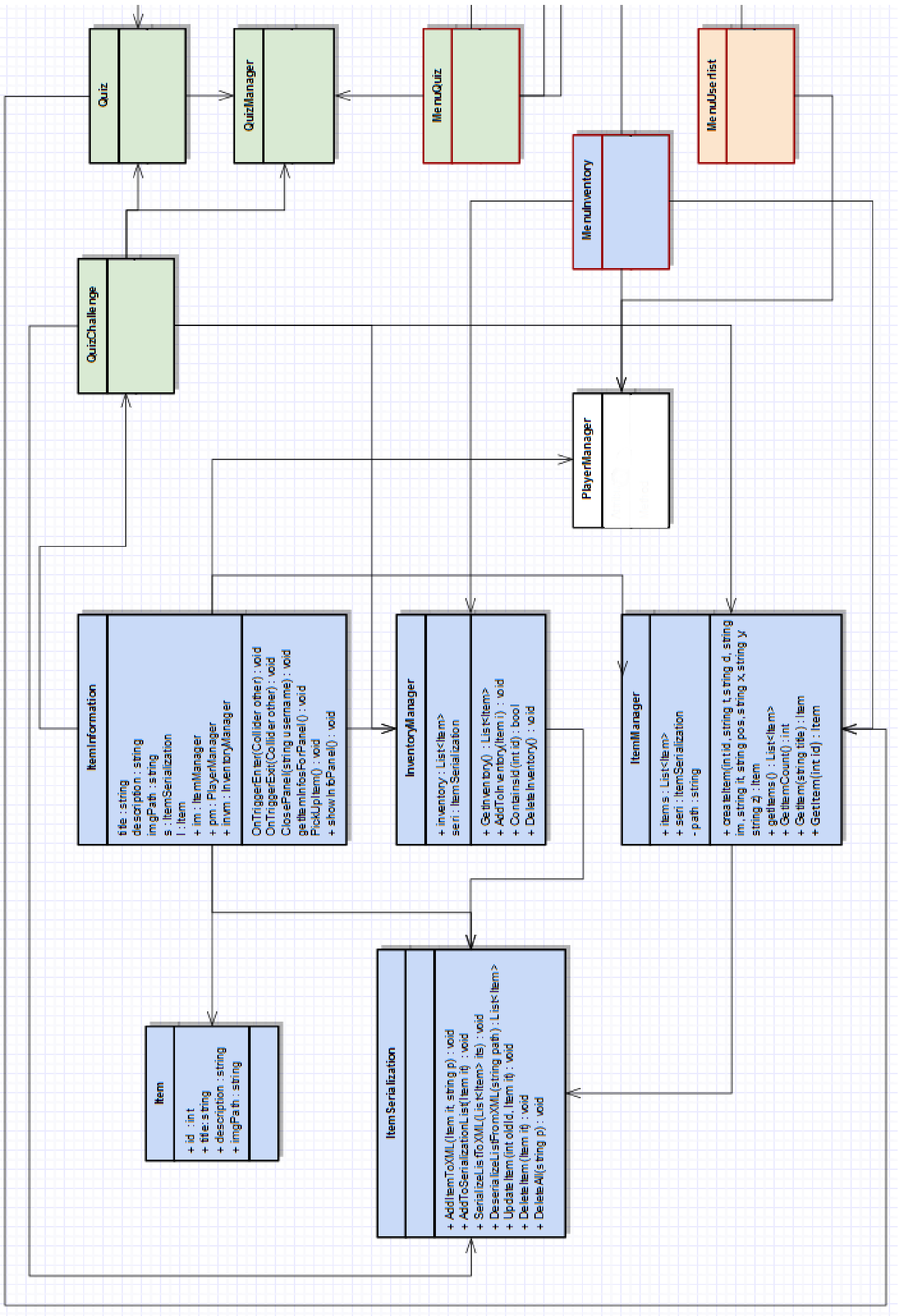


Figure 4.4.: Class diagram of the item tool

## Item Pick-Up

This section focuses on the item pick-up and according implementational details.

### Description

As described above, upon collision with an item the item information panel is displayed. If the administrator configuration provides for pickup questions they are asked a question before the information panel is shown. Only certain items have pickup questions attached, but this could be extended for all items.

### Implementation

Game Objects:

- items (currently: Osiris, Isis, Seth, Horus, Anubis, Was, Bastet, Apis, Alabaster Vase, Scales, Eye of Horus, Atef Crown, Sarcophagus, Ankh)

Scripts:

- `ItemInformation.cs`
- `QuizChallenge.cs`

XML:

- `quiz.xml`

In `ItemInformation` a method is triggered on collision of the player with the item. The information panel is prepared but not shown. The `QuizChallenge` script has two important methods `NoChallenge(int itemId)` and `CheckChallenge(int itemId)`. The first method is called in case the administrator configurations disabled the pickup question. In this case the item information panel is simply displayed without asking a question before. If the pickup option is enabled the `CheckChallenge()` is called. This method initializes a quiz panel for certain items. A random questions regarding one of those picked up items are then be chosen from the `quiz.xml` file and displayed if the item demands a pick-up question. If the question is answered correctly the information panel is shown, otherwise the player gets another chance to choose the correct answer as it is not the final quiz yet and only for training and memorization purposes.

## Student Inventory

This section focuses on the implementation of the student inventory.

### Description

The player can view his/her inventory in the menu under inventory. A panel with a list of all items in the game appears. The items are color-coded. Items already picked up are blue, items not yet picked up are red and items that this role cannot pick up are grey. The player can click on items in the list and, in case the player already picked up this item, the information is displayed on the right side of the panel.

### Implementation

Prefabs/ Game Objects:

- InventoryPanel

Scripts:

- `InventoryManager.cs`
- `MenuInventory.cs`

XML:

- `inventory.xml`

The `InventoryManager` script handles read/write-interactions with the XML-file, where the user's current inventory is saved. `MenuInventory` handles the menu panel displaying the inventory, clicking on items and displaying the regarding information. First the InventoryPanel is instantiated. As this prefab contains several different panels all panels and UI elements have to be initialized (FindPanels(), FindButtons()). In the OnGUI() method which is regularly called the list of items is displayed with entries in the according colors. If an entry is clicked on and is in the inventory the information is shown.

## Administrator Item Management

This section focuses on the implementation of the administrator item management.

#### Description

The administrator can also display all items in the game. He/she can see and access all item's information, therefore, no color-code is necessary.

#### Implementation

The same prefabs, scripts and xml-files are used as for the student inventory. The inventory panel is handled and displayed by the `MenuInventory` script, as with the student.

#### Future Work

An important future feature is to add new items to the games dynamically during game play. In the current prototype items cannot be added during game play. There were some attempts to prepare this feature, such as "Add Item" and the corresponding "Delete Item" buttons in the administrator's inventory panel. There was also a user interface implemented to input a new item, including name, description, a picture file chooser, a file chooser for the actual item object, scale and a map for choosing the position on which to instantiate the item in the game. However, these preparations are not finished and tested as this exceeded the scope of this project.

### 4.2.5. Roles

This section describes the implementation of the role tool.

## Student Roles

This section focuses on the implementation of the student roles.

#### Description

The student roles contain information regarding the whereabouts of the items and, more important, pick up restrictions. There are currently four different roles and each role is allowed to pick up certain items. The player can check his/her role information in the menu under user information.

### Implementation

Game Objects:

- RoleManager

Scripts:

- `Role.cs`
- `RoleManager.cs`
- `RoleSerialization.cs`
- `MenuUserList.cs`

XML:

- `roles.xml`

The `Role` script contains the role information that is stored in an XML-file. `RoleSerialization` reads the roles from the file and `RoleManager` handles these interactions with the serialization script. In the `OnGUI()`-method of `MenuUserList` the user's role is displayed once he/she opens the user information panel of the menu. The current role is saved in the `PlayerManager` script.
The class structure of the role tool can be seen in figure 4.5.

## Administrator Role Management

This section focuses on the implementation of the administrator role management.

### Description

The administrator can change roles of students in the game by selecting the user-entry in the menu which opens a panel containing a list of users currently in the game. When the administrator chooses one player the option of the four different roles appears. Once the administrator saved the new role settings the role of the according player is changed over the network.

### Implementation

The same game objects, scripts and XML-files are used as above. The menu handling including opening the panel, displaying the current userlist and changing

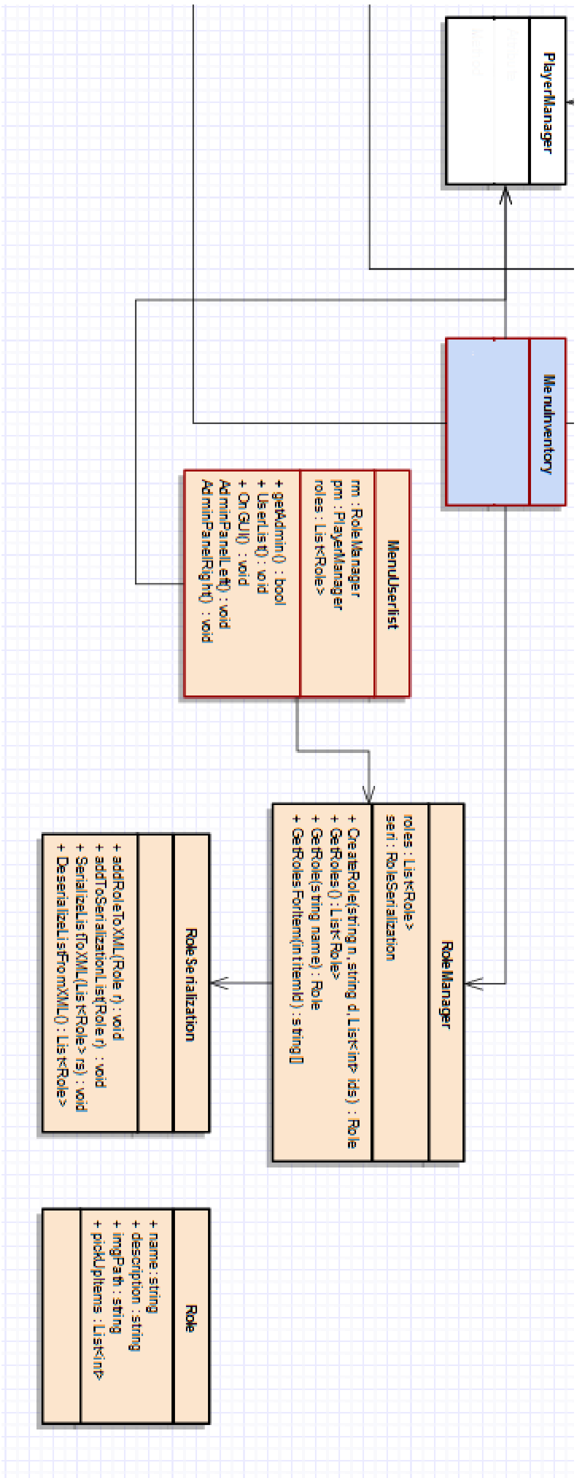


Figure 4.5.: Class diagram of the role tool

a player's role locally is handled in `MenuUserList`. The `PlayerManager`'s `PhotonView` is used to change the role over the network.

**Future Work**

Possible future work ideas regarding roles include the dynamic introduction of more roles during game play and additional characteristics or features of roles (beyond pick up restrictions).

### 4.2.6. Quiz

This section describes the implementation of the quiz tool.

**Description**

The game comprises two different quizzes. On the one hand, there is the quiz at the end of the game. Once a player has collected all relevant items and information, he/she can take the quiz to test their memorization skills. If the game is completed successfully the player proceeds to the next level of the game, in this case the end of the game. On the other hand, there are the pickup control questions that test the recollection of already picked up items during the game. Both quizzes draw their questions from a common question pool.

**Implementation**

Game Objects:

- Quiz
- Camels (quiz-collider)

Scripts:

- `Quiz.cs`
- `QuizChallenge.cs`
- `QuizManger.cs`
- `QuizNode.cs`

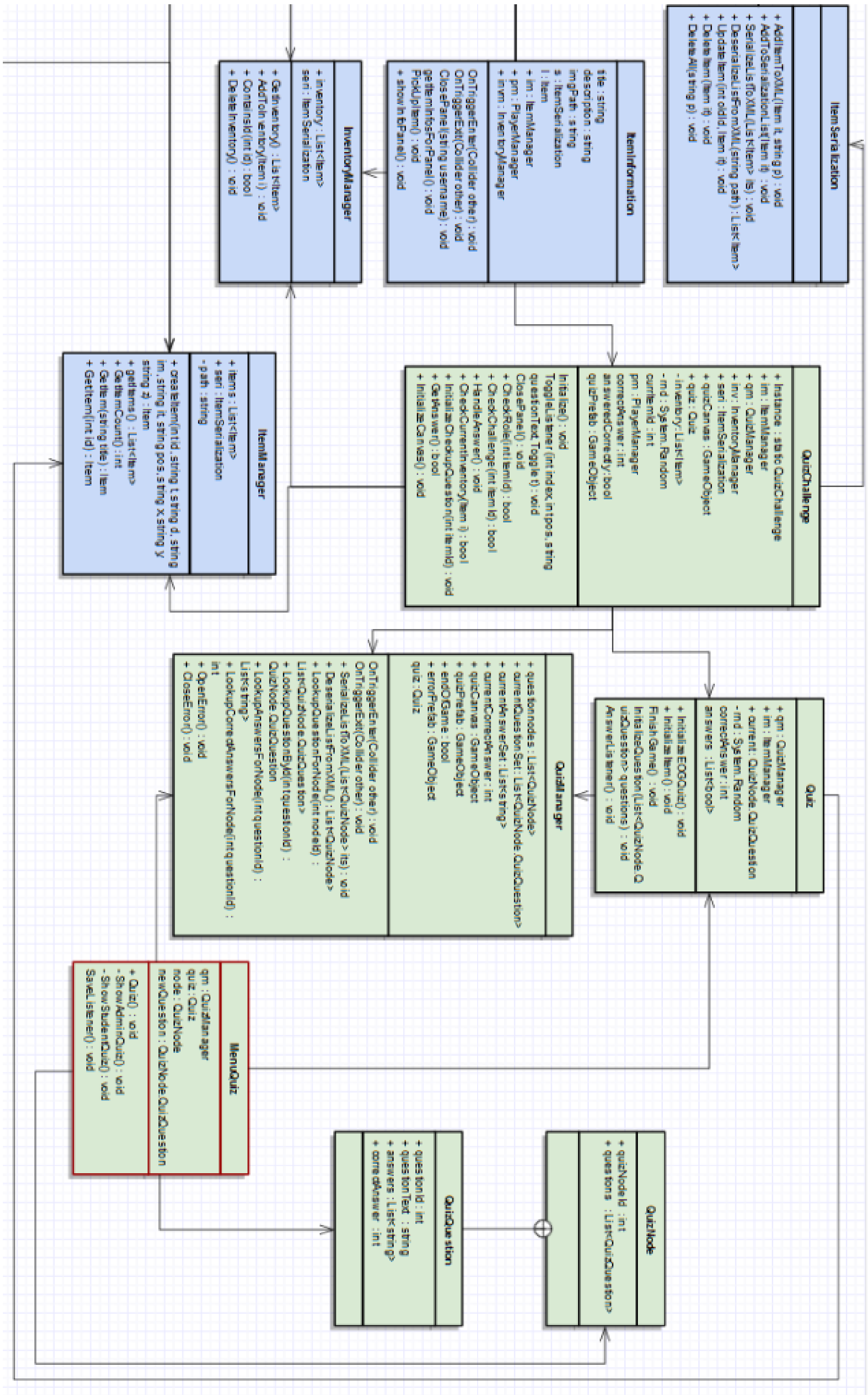


Figure 4.6.: Class diagram of the quiz tool

XML:

- quiz.xml

QuizNode is the definition of the XML-file variables. Each QuizNode has an id and a list of questions. Each question, in turn, consists of an id, a question text, a list of answers and a number indicating the correct answer. The QuizManger script handles the serialization of the XML-file, as well as opening and initializing the quiz panel when entering the quiz-collider. The main scripts are Quiz and QuizChallenge. First of which is responsible for the end-of-game-quiz. Questions from each item-category are picked randomly.
The quiz class structure can be seen in figure 4.6.

## Student Quiz

This section focuses on the implementation of the student quiz.

### Description

As described above there is the end-of-game-quiz and pick-up challenge questions that the student has to answer.

## Administrator Quiz Management

This section focuses on the implementation of the administrator quiz management.

### Description

The administrator can add quiz questions in a user-interface as part of his/her menu.

### Future Work

Future features that can be added to the quiz include different types of questions, such as text-based answers, instead of purely multiple-choice questions, and more quiz management. An administrator interface could be created for compiling quizzed manually instead of picking questions randomly automatically. Editing and deleting of questions is also not yet possible.

### 4.2.7. Collaboration Tools

There are three tools supporting the collaboration in the game

1. Text Chat
2. Chatbot
3. Itemboard

They are described in following sections.

## Chat

This section focuses on the implementation of the textchat.

**Description**

The textchat is accessible via a button on the top left game screen corner. It can be dragged around the game screen. The chat consists of a chat history panel and an input field for new messages. Each message takes the format: [Time - Name: Message].

**Implementation**

Game Objects:

- TextChat

Scripts:

- `TextChat.cs`
- `TextChatController.cs`

The chat is synchronized over the network via the PUN. The scripts that handle the chat are `TextChat` and `TextChatController`. In `TextChat's SubmitMessage()`-method the input field is read once the submit button or enter is pressed. Then the message is passed on and a chat entry, consisting of [Time - Name: Message], is created in the `AddChatEntry()`-RPC-method. As it is a remote procedure call it is called for every player in the game, therefore, the chat is synchronous for everyone in the game. The message is then added to the chat history and displayed via the `DisplayMessage()`-method.

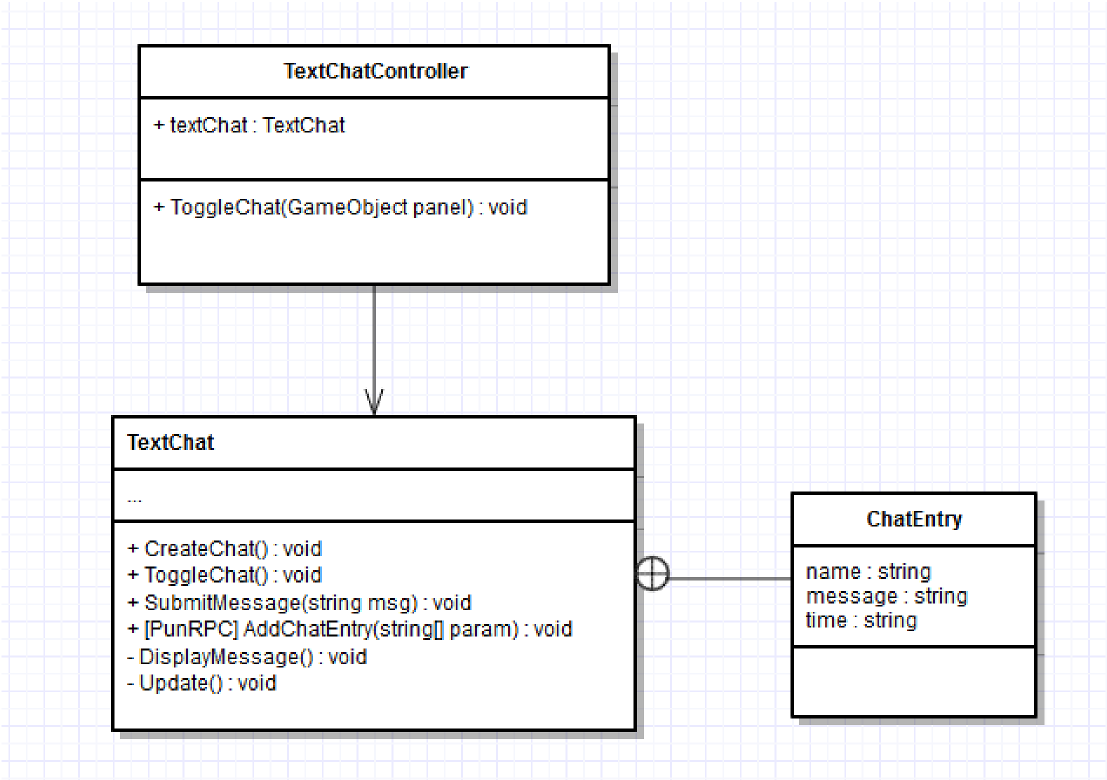


Figure 4.7.: Class diagram of the textchat tool

`TextChatController` handles the toggling of the chat panel. The class structure can be seen in figure 4.7.

An issue that occurred when implementing the chat was that firstly, all other panels are closable by pressing the 'X'-key and secondly, the 'WASD'-keys are also movement input keys. Therefore, either the controls had to be turned off while the chat window was open or it would close when accidentally pressing 'x' during typing or the avatar would move around when using the 'WASD'-keys. It was decided that the movement inputs would remain, as it does not really matter if the avatar moves around a bit while typing. The panel-close-function of the 'X', however, was turned off, while the chat panel is open, as accidentally closing the chat during typing seemed a nuisance.

## Chatbot

This section focuses on the implementation of the chatbot.

### Description

A chatbot is an automated answering chat system. Instead of talking to a real person, the system answered with predefined sentences. The aim of chatbots is often to mislead people into thinking they are talking to a real person, as it tries to answer as ”humanly” as possible.
In this project a simple decision tree chatbot was developed, as exampled shown in figure 4.8. When opening the chatbot a begin question is given and answering possibilities. Then depending which answer is chosen according follow-up questions are provided, leading to a relatively sensible conversation.

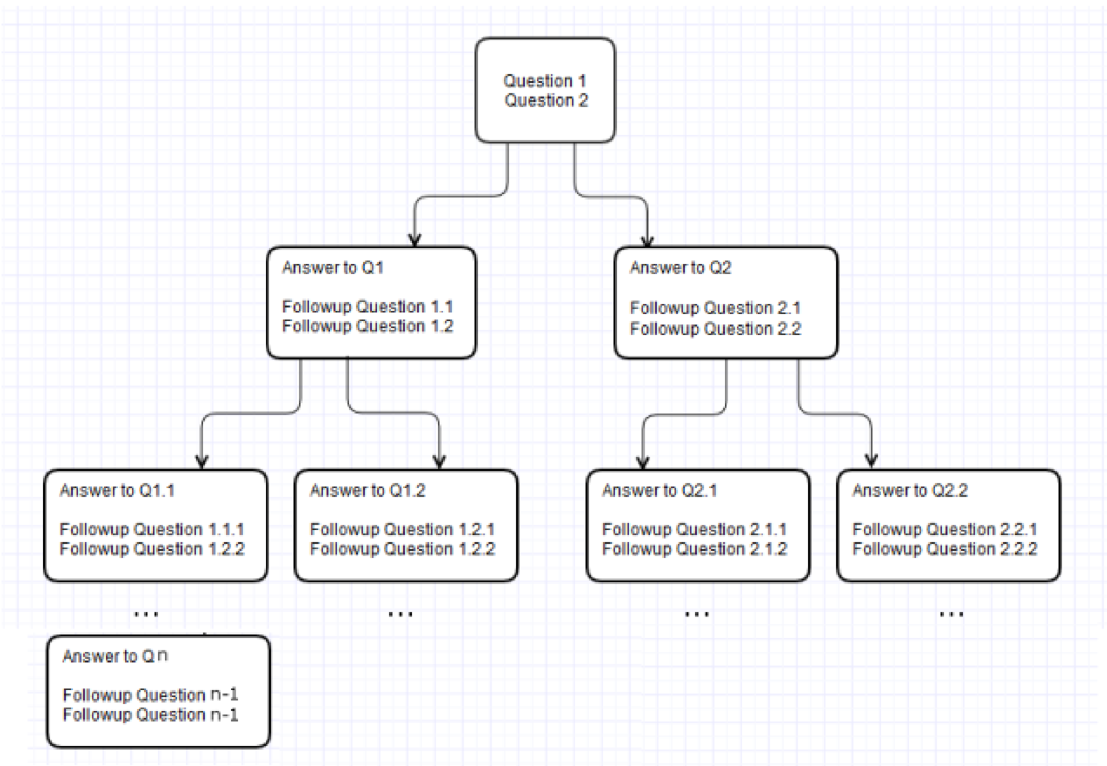


Figure 4.8.: Chatbot Decision Tree

The chatbot is a person in the game environment. Once a player collides with the chatbot person's collider the chatbot panel opens. There are a few predefined questions on selection. Upon choosing one the chatbot answers automatically and offers a new selection of follow-up questions.

### Implementation

Game Objects:

- ChatbotPerson
- ChatbotManager

Scripts:

- `Chatbot.cs`
- `ChatbotManager.cs`
- `ChatbotQuestionNode.cs`

XML:

- `chatbot.xml`

The chatbot decision tree questions are stored in a XML-file. Each question node has an id and a list of questions. Each question in turn has an id, a question text, answer text and an id for the follow-up question, as defined in `ChatboatQuestionNode`. The `Chatbot` script opens, initializes, updates and closes the chatbot. The `ChatbotSerialization` script handles the access to the XML-file. The class structure can be seen in figure 4.9.
Listing 4.3 shows an excerpt of the chatbot's XML-structure. Question node zero contains the first questions the player is offered as selection. If the player chooses *"Hello, who are you?"* the answer is *"Hello, I am here to help you. Do you need general information or item specific information?"* and the next questions displayed are the ones contained in question node four, as demonstrated.

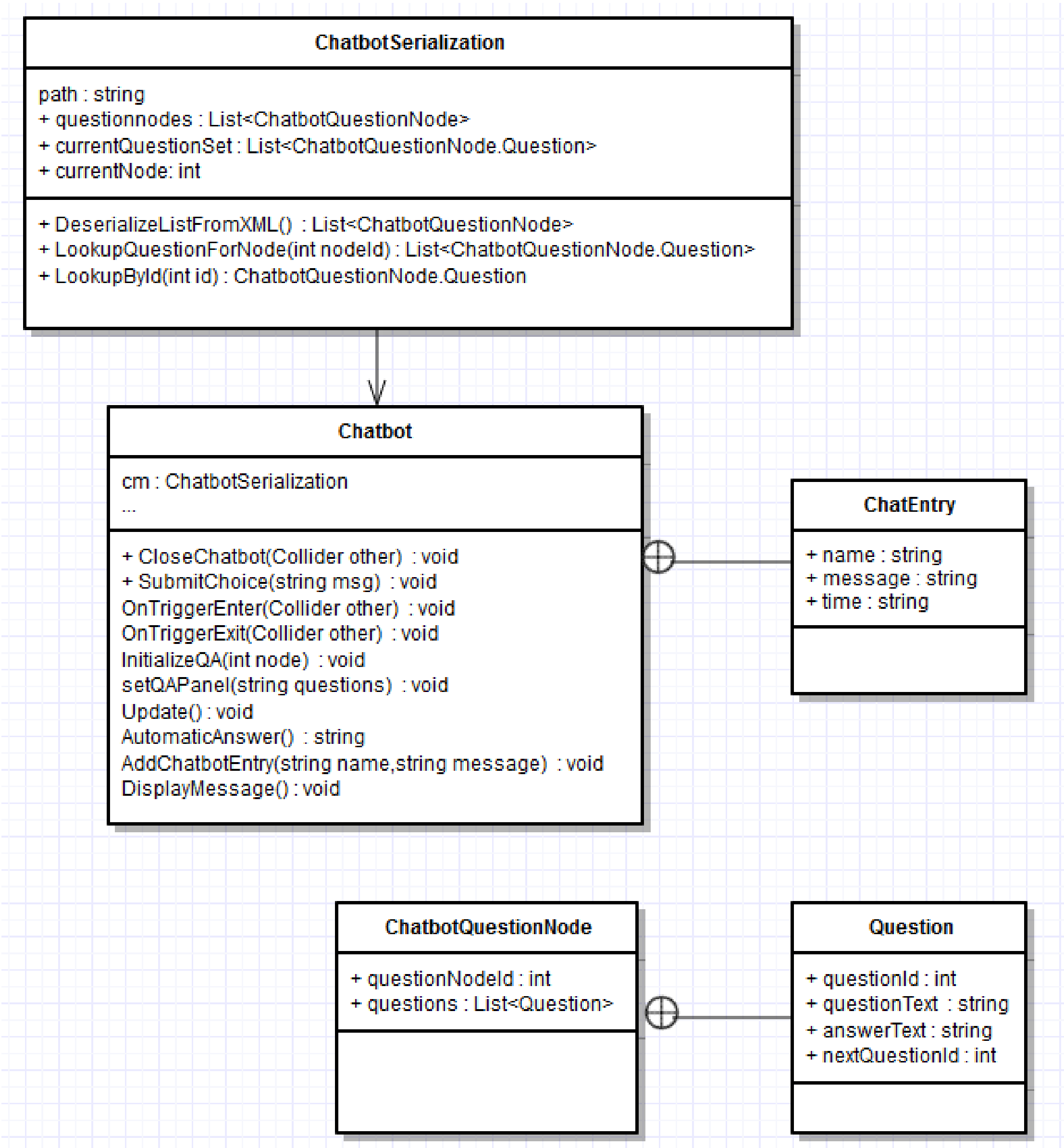


Figure 4.9.: Class diagram of the chatbot tool

Listing 4.3: Chatbot XML

```
<ChatbotQuestionNode>
  <questionNodeId>0</questionNodeId>
  <Questions>
        <!-- item specific infos ?? -->
        <Question>
      <questionId>1</questionId>
      <questionText>Hello, who are you?</questionText>
      <answerText>Hello, I am here to help you. Do you
      need general information or item specific infor-
      mation?</answerText>
      <nextQuestionId>4</nextQuestionId>
    </Question>
        <!-- general info ?? -->
    <Question>
      <questionId>2</questionId>
      <questionText>What shall i do now?</questionText>
      <answerText>Look for Egyptian artefacts and statues.
      </answerText>
      <nextQuestionId>1</nextQuestionId>
    </Question>
  </Questions>
</ChatbotQuestionNode>
```

## Itemboard

This section focuses on the implementation of the itemboard.

### Description

The itemboard is a place for information collection and sharing, similar to a whiteboard or pin board. It consists of four information slots that are buttons to add items. Once a button is clicked a panel is drawn that lists all items in the player's inventory. The player can choose one of them and the according information is pinned into the slot on the itemboard. Information slots can be deleted again or dragged to another slot position. Multiple itemboards can be added.

**Implementation**

Game Objects:

- Itemboard
- (Square-Tent)
- ItemboardManager

Scripts:

- `ItemboardManager.cs`
- `ItemboardAddBoard.cs`
- `ItemboardAddItem.cs`
- `ItemboardDeleteBoard.cs`
- `ItemboardDeleteItem.cs`
- `ItemboardDragHandler.cs`

The itemboard consists of a canvas and several UI elements. There is a game object ItemboardManager containing the `ItemboardManager` script, handling slot ids, a Dictionary of all currently used slots, and number of itemboards. The itemboard is located inside a square tent which contains a collider disabling the rotating view upon entering. Therefore, on adding another itemboard a second tent is also added to the scene. Other important scripts are `ItemboardAddBoard`, `ItemboardAddItem`, `ItemboardDeleteBoard` and `ItemboardDeleteItem`, handling the adding and deleting of items on the board and new boards. The `ItemboardDragHandler` handles the dragging of slots in the itemboard. The class structure can be seen in figure 4.10. The itemboard is synchronized over the network via the PUN `PhotonView` script. An RPC-method is called for removing the Add-Button to mark the slot as used, to add the information panel to the slot, to delete it or when dragging it.

### 4.2.8. Settings and Configuration

**Description**

The administrator's configurations include the option of (1) a gamification approach, (2) the map, and (3) pickup questions. The gamification effect is a row of empty stars in the corner of the game screen (one for each item to be found) which turn blue once the player picks up an item. The map is a feature added during the development of this prototype in order to simplify navigation

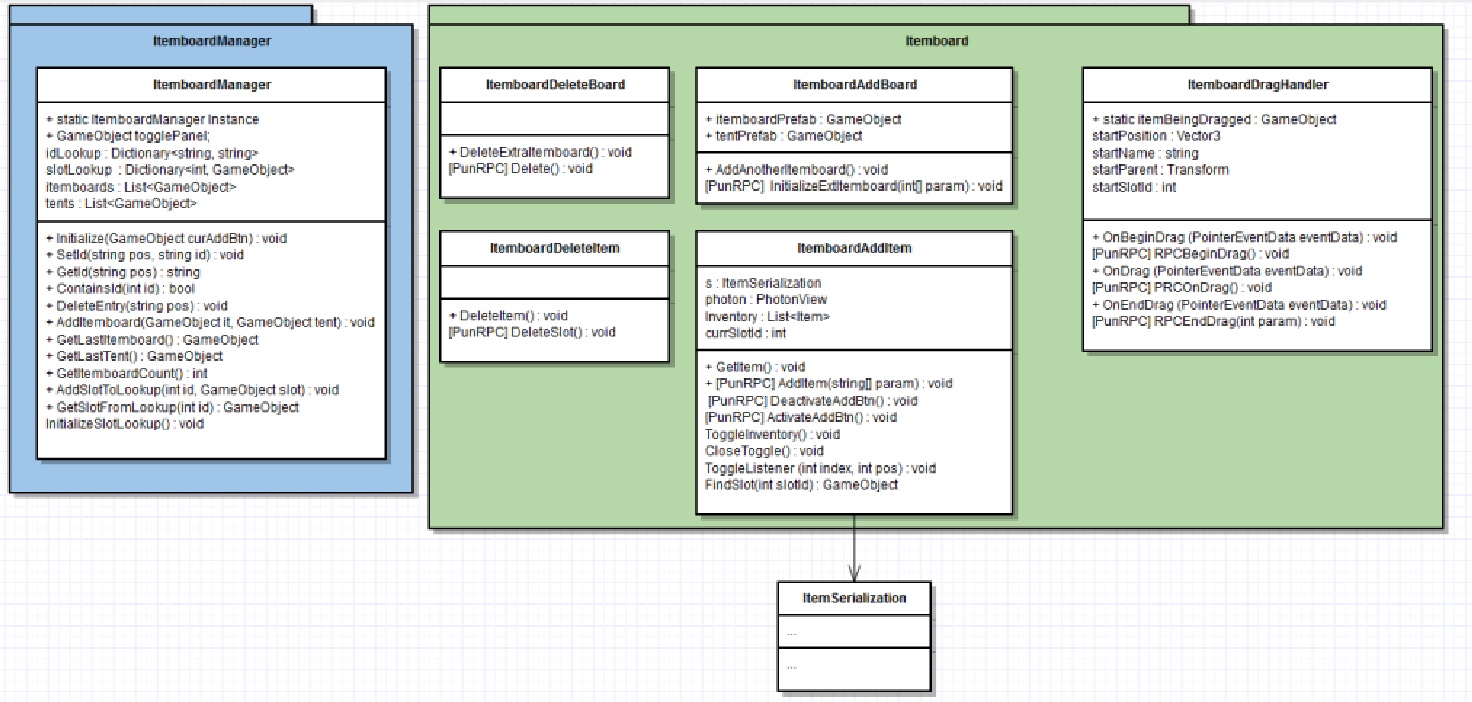


Figure 4.10.: Class diagram of the itemboard tool

in the game environment and especially the pyramid maze. The last option enables a check-up question that has to be answered correctly before the player is able to pickup a new item. The question is randomly picked from a pool of questions about an item that the player already has in his/her inventory.

**Implementation**

Game Objects:

- Menu/MenuCanvasStudent or Menu/MenuCanvasAdmin
- Menu/MenuCanvasStudent/NavigationText
- Menu/MenuCanvasStudent/HelpText
- PanelCanvas

Scripts:

- `NavigationText.cs`
- `PanelController.cs`
- `PanelDrag.cs`
- `PanelResize.cs`

XML:

- `config.xml`

The administrator can change these parameters in a settings entry in the game's menu. They are saved in an XML-file. This configuration-file also contains the administrator username and password combination, which cannot be accessed or changed during game play.
Depending on whether the administrator or a student is logged in different menu canvases are shown. The student canvas includes a NavigationText and a HelpText. The first one is set and reset when sudden actions happen that are controllable by the keyboard, such as panels opening on collision. Then the text elements show a message such as "Press 'X' to close panel". After the according key is pressed the text element is reset to be empty again. This is handled in `NavigationText`. The second one, HelpText is always displayed containing the keyboard shortcuts for easier control of the game.
Opening and closing of most panels is done via the `PanelController` script that contains a Dictionary of all open panels to keep track of. Once a panel is opened the `mouselook`-variable in the player's movement script is set so the world stops rotating. This makes navigating in the panel easier. Some

panels can also be dragged across the screen or resized with `PanelDrag` and `PanelResize` respectively.

## Progress Stars

This section focuses on the implementation of the progress stars.

### Implementation

Game Objects:

- Menu/GamificationStarManager

Scripts:

- `GamificationStar.cs`
- `GamificationStarManager.cs`

The progress stars are instantiated by `GamificationStarManager` and set to blue upon picking up an item by`GamificationStar`.

## Map

This section focuses on the implementation of the map.

### Implementation

Game Objects:

- MapPanel

Scripts:

- `Map.cs`
- `MapDrag.cs`
- `MazeLevelManager.cs`
- `MazeSecretDoor.cs`

The map is opened by the `Map` script, however the navigation text for pressing 'X' and the mouselook-variable are set like with any other panel. Depending on where the player currently is located the map shows an image of the outside environment or the according level in the pyramid. Moreover, the actual position of the player is calculated and shown in the map. `MazeLevelManager` sets the player's position to the according level by checking colliders that are installed at every staircase and `MazeSecretDoor` does the same for the main door of the pyramid. When somebody walks in the position is set to lowest level and vice versa.

### 4.2.9. Log System

This section focuses on the implementation of the logging system.

**Description**

The log system is an analytic tool in the project. It logs all interactions of the players with the game, such as item pickup, using the itemboard, chatbot or chat, and taking the quiz.

**Implementation**

Game Objects:

- LogSystem/LogSerialization
- LogSystem/LogManager

Scripts:

- `LogModule.cs`
- `LogSerialization.cs`
- `Logging.cs`
- `LogManager.cs`
- `LogStats.cs`

XML:

- `logs/[username].xml`

Figure 4.11 shows the class structure of the logging elements. The logging system writes each interaction into a XML-log-file that is named after the user. For each interactable tool in the game there exists one module (Itemboard, Chat, Quiz, Chatbot) in the XML-file. For each interaction with this module a new activity is created containing information about the interaction and added to the according module. The variables of these modules and activities are defined in `LogModule`.

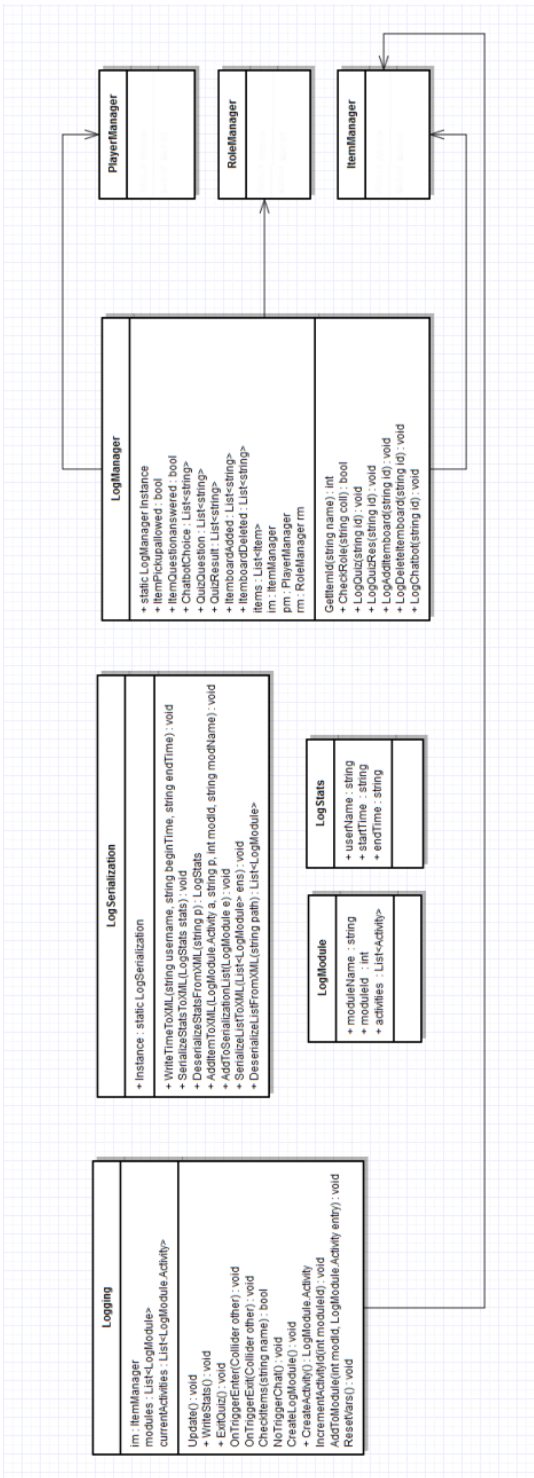


Figure 4.11.: Class diagram of the logging elements

There were several options where to use the logging system. Either each person or each interactable object has a logging script attached or there is a single logging unit that is called at every player's loggable interaction. In this project the first option was implemented. Each person has a `Logging` script attached that collects information about the interaction and creates a new activity upon exiting the collider of the object or upon stopping using it. The activity is then added to a module in the XML-log-file if this module already exists or a new module is created. Reading and writing the XML-file is done by the `LogSerialization` script. The `LogManager` script handles several helper functions for the logging process. At the end of each game the game statistics, defined in `LogStats`, are written to the log file, including start and end time of this player's game and the username of the player.

**Future Work**

The logging system has potential for improvement, as it is only a first prototype. For example, more tools or interactions could be logged or more detailed information about the interaction collected. Another approach to logging would be to have one log file for each game instead of one log file for each user.

## 4.3. Summary

In this second prototype above described modules were implemented in Unity. Unity offers countless tutorials and documentation which made it relatively easy for a beginner to learn and use the program. However, there are hardly any pre-defined modules that can be integrated out of the box, which made reproducing the first prototype in Unity a bit cumbersome at times.

As everything had to be programmed from scratch, a few problems occurred. The biggest was the add-item functionality of the administrator. While OWL offered useful tools for positioning and scaling the item in the world, Unity had nothing of that kind which made it too big a feature to implement in the scope of this project. The pyramid 3D model was reused from the same source as the first prototype but had several flaws, such as missing colliders in walls and floor (which lets players walk through walls and fall through floors). The model was, moreover, in one piece and separate level models had to be created during this project for easier handling and navigation of the items inside.

Future work that became apparent after programming could include adding items during game-play, extending the logging system, refining the quiz with different kinds of questions and dynamic introduction of new roles during game-play. The evaluation part might offer more features to be added in future.

Summing up, all modules and tools included in the requirements were implemented. The only feature not adopted from the first prototype is the dynamic addition of items during game-play which was too cumbersome a task to do in the scope of this thesis.

# 5. Showcase Scenario and Application of Learning Concepts

In the following chapter learning scenarios implemented in this project will be described. The Egyptian scavenger hunt scenario was revisited from the first prototype (Tomes, 2015). This section will show screen shots of the game, as well as describe the learning modules implemented in more detail and explain how the learning methods got integrated in the game.

## 5.1. Egyptian Scavenger Hunt Scenario

The Egyptian learning world (see figure 5.3) is based around a game area where items with attached pieces of information, that form a story, are located. Figure 5.1 shows the environment from top view divided into several areas, where the itemboard, the quiz or the chatbot are located. The main part is the pyramid maze where items can be found. There are several pyramids, the Sphinx and desert area to explore. One of the pyramids accessible. There is a maze inside where students can also find items. Moreover, there are some objects indicating a meeting area for the players. There are several tents and a bigger meeting tent including the Itemboard. Another area is used for the quiz. Figure 5.2 shows a learning round trip through the virtual world with screenshots. Figure 5.4 shows the settings menu on the screen where students find their user role information, inventory, hints, key shortcuts, the chat and the map.

The student can explore the world and start looking for the items hidden throughout the area. It was developed as a first-person game, which refers to the students' perspective from the viewpoint of the player avatar. The students can choose a username and one of two avatars when logging into the game (see figures 5.5 and 5.6).

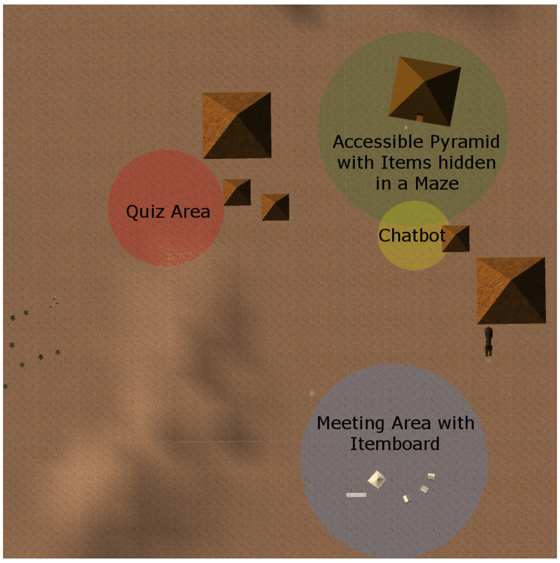


Figure 5.1.: VW Game Environment divided in important areas

In the game they will then see other people represented by their avatars with name tags above their heads. This makes interactions between players in the game more realistic and, thus, facilitates students' immersion into the game. As discussed in literature, immersion is closely related to engagement which in turn is important for the learning effectiveness in games. This is one of the key benefits of learning in virtual worlds over traditional learning environments. The increased perception of immersion in the game influences the motivation and commitment in a virtual world. The authenticity of the world, the avatars of other people and the tools in the world are, therefore, very important. In this game's development special care was, hence, taken when creating the environment.

While exploring the area, there are several tools that will help the student finds his/her way - hints and a map - as described in section 5.1.1. To keep the student engaged there are multiple challenging aspects. To integrate problem-based learning and, thus, make it more challenging, items are not just randomly placed somewhere in the world but sometimes hidden. Moreover, students are assigned different roles which restrict them from picking up certain items. This means students have to gather all the information hidden with the items but might not be able to pick up all of them themselves. These "challenges" engage the student and promote creative and logical thinking, as discussed in section

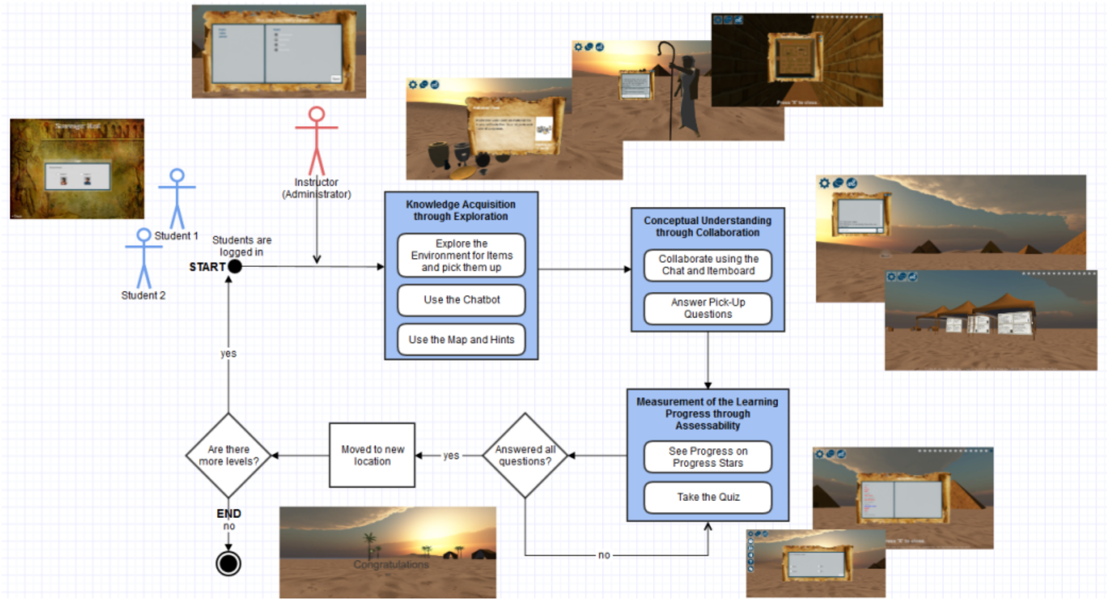


Figure 5.2.: Learning round trip in the virtual Egyptian learning world with screenshots

5.1.2.

This is also a way to promote collaboration between the students in the world. As no one can achieve the learning tasks alone they are encouraged to work together. Students have to communicate or negotiate exchange of information in order to master the learning tasks and finish the game. Sharing and discussing the hints given in their role description, the information about their picked-up items or knowledge about the place of a certain item is an essential part of the game as it stimulates team work and communication skills. This is supported by collaborative tools, such as a chat and itemboard, which are described in section 5.1.3.

Once the student found all the items or is in possession of all information necessary to form the whole story, he/she can take the quiz. The quiz module is further described in section 5.1.4.This concludes the student's learning round trip.
The instructor can login as administrator and assign roles and change settings. He/she can, moreover, review the log files of the students afterwards to see the student's behaviour and interaction in the world. This module is described in section 5.1.5.

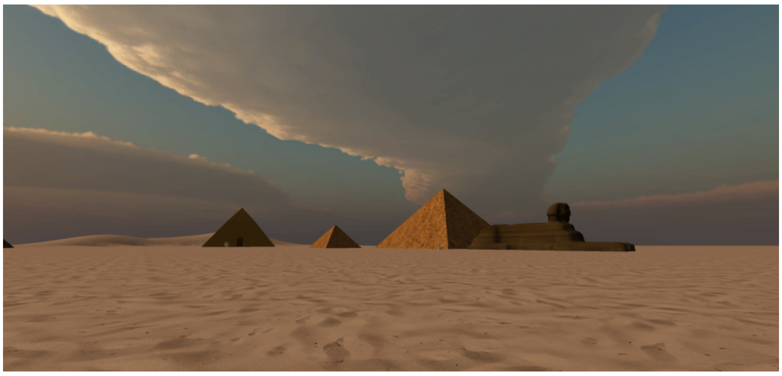

Figure 5.3.: Egyptian Virtual World

Figure 5.4.: Settings menu which is always visible on the screen

### 5.1.1. Exploratory Module: Storyline, Hints, Map

For introduction purposes there is a introductory statement at the start of the game that teases what the story is about, as shown in figure **??**. It, moreover, gives the player a general idea of what he/she is supposed to do and where to find further information. This should be enough instruction to play the game but there are several helping tools during game-play. A menu in the top left corner offers settings, which include user information - referring to the role description -, the player's inventory, and buttons to access the chat, a map of the player's environment or hints what to do. The menu and the hint panel can be seen in figure 5.8. The map shows the player's position in the area. It, moreover, changes depending on the player's location. If he/she is outside the pyramid the map shows the outside map (see figure 5.9), whereas maps

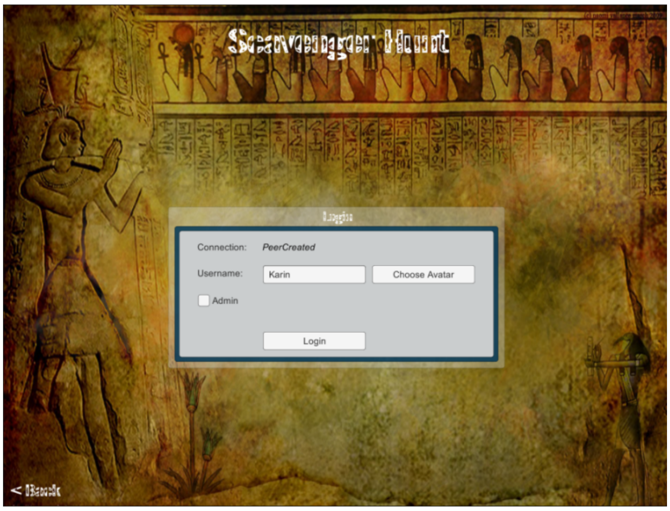


Figure 5.5.: Login Screen

of the according level of the pyramid are shown once the player is inside the pyramid (see figure 5.10). This should help the player's orientation in the game. Because although the player should be challenged he/she should not feel lost and overwhelmed with the world. These tools help the exploration phase of the player. The other menu items will be discussed in the following sections.

Equipped with these skills and knowledge users can explore the desert area and the maze inside a pyramid to find the items. The Egyptian world gives students the opportunity to explore in a safe environment, as proposed by De Freitas (2008). The student can make choices of his/her own, such as which way to go, which items to pick up first or which means of communication he/she wants to use, and explore and experiment to find a path of learning that feels natural to the learner as suggested by Rieber (2005). Each learner is responsible for their own learning progress, as the concept of individual accountability suggests, however the players will only get the best possible learning outcome if they work together to solve the learning tasks (positive interdependence). This also promotes interaction between them.

An addition to the game extending the first prototype are the progress stars, as shown in figure 5.11. In the top right corner of the game screen grey stars can be seen. Whenever an item is picked up a star turns blue. This feature is supposed to enhance the fun of finding, as well as serve as a reward once picked up. Moreover, it is a progress indicator for the player which further

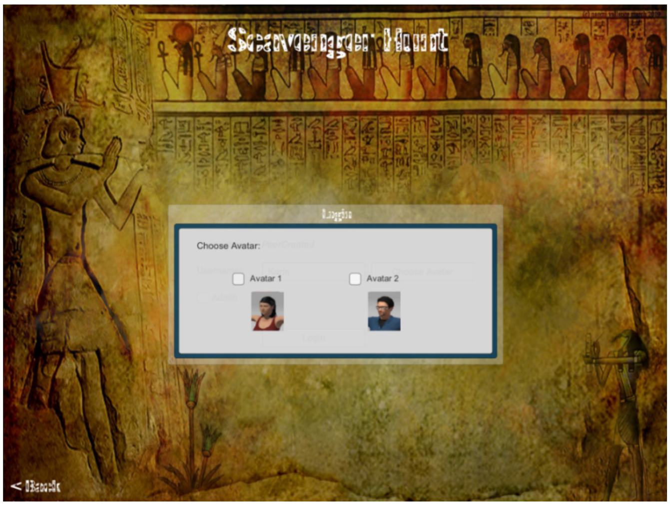


Figure 5.6.: Choose Avatar screen

increases the motivation and engagement in the game.

Summing up, exploratory learning in this game is facilitated by offering an authentic Egyptian world where students, represented as avatars, can walk around and interact. Each person sees the game through the first-person-view which contributes to the immersion in the game. There are several choices the user can take to create the optimal learning path, while being encouraged to collaborate at the same time. Tools that help exploring the environment are the begin statements, hints and the map, along with progress stars showing how


Figure 5.7.: Introduction

Figure 5.8.: Main menu and hints panel


Figure 5.9.: Map of the outside environment.

many more items there are to find.

### 5.1.2. Challenge-based Modules: Items, Inventory, and Roles

The main focus of the learning world lies on finding items that are hidden throughout the game environment as described. Moreover, there is a maze in one of the pyramids that makes finding the items a bit more challenging. Attached to these items are pieces of information that are a part of the story the game tries to tell. The items are glowing while not picked up, so players know which objects in the game area are of interest. Once they are picked up they stop glowing for that person. Figure 5.12 shows an item in the environment and figure 5.13 an item information panel, that appears when the player collides with the item.


Figure 5.10.: Map inside the pyramid maze.


Figure 5.11.: Progress stars in the top right corner - star turns blue after item pick up

Some items, however, can not be picked up quite so easily. A question about another randomly picked item already in the player's inventory, has to be answered correctly first, before the information panel of the new item will appear. This should challenge the students to not just pick up the items without reading or remembering the information but actually pay attention. Answering questions about the subject before the final end-of-game-quiz might increase memorization and comprehension of the subject, and therefore benefit the overall learning outcome.

Another challenge consists of the student roles. Roles were invented to create a distinction between players. The administrator can assign roles to the students. A role consists of some information, usually hints on how or where to find the items or how many there are. Roles, moreover, restrict players from picking up any item. This is intended as another incentive to collaborate with other

Figure 5.12.: Item in the scene


Figure 5.13.: Item Information Panel

students. As each player starts with different knowledge, the game is highly dependent on the players' abilities to collaborate, share and discuss the items. By providing role-dependent hints and pick-up restrictions, players have to work together and negotiate exchanges of information to gather all parts of the story. Hence, they are challenged to make a decision about working together and about how much information they are willing to share. It will force them to use their communication skills to get new information in exchange for their own knowledge.

Therefore, students are engaged in learning activities as proposed by Prince (2004). That way players do not wander around aimlessly and hence lose interest in the game and subject but are engaged in the "Scavenger hunt" as well as interacting with other players. Another important approach used here is to not expose students to vast amounts of new information at one time but letting them discover small parts one after the other, supporting the steady evolvement of the students' knowledge. This way of constructing, creating and developing their knowledge and make meaning for their own learning is seen as an important pedagogical theory to engage learners in-world.

The roles and restrictions are what De Freitas (2008) would call *"potential for problem – or challenge-based learning"* which then leads to different kinds of collaboration as suggested by Bonwell & Eison (1991). Challenging students to collaborate to master the learning goals, moreover, *"promotes group reflection, multiple perspectives and collaborative construction of learning which can be enhanced by using reflection to assist students in framing and reframing the problems"*, according to McDonald et al. (2014).

The teacher's role as administrator of the game allows adding new items to the game. This feature is not finished and tested, as there are no built-in tools in Unity allowing the placement of items in the environment during game-play. However, adding items when not in game-play is straightforward. This should facilitate easier creation and maintenance of the learning environment for teachers with little technical skill.


Figure 5.14.: User information panel with information regarding the role

The inventory is a feature supporting the development of each student's story base. Each individual inventory lists all items of the game but highlights them according to the categories "picked-up already" (blue), "not yet picked-up" (red) and "not able to be pick-up" (grey). This distinction demonstrates students' progress in the game and promotes further involvement and exploration of the game.

Concluding, there are several features in the game promoting challenge-based learning. Student roles with pick-up restrictions challenge the player as well as encourage collaboration and communication. The player has to figure out which information is accessible to him/her and how to get all information. Moreover, pick-up questions promote revision of the information learned. This


Figure 5.15.: User role change panel from admin view


Figure 5.16.: User inventory (blue = picked up, red = not yet picked up, grey = can't pick up)

is a vital aspect of problem-based learning, to choose a path to overcome the challenge and watch the story unfold slowly. The aim of the game was for students to find pieces of information and have the ability to link all the details to form a bigger picture.

### 5.1.3. Collaborative Modules: Chat, Chatbot, Itemboard

Section 2.3.2 described that virtual worlds can be used as a tool for group-based learning and collaborative problem solving. *"Communication and social interaction are at the centre of virtual world social experience. Virtual worlds therefore present an ideal platform for the engagement of learners in constructivist-focused educational practice."*, according to Moschini (2010). The structure of the game, therefore, encourages collaboration between the players to a point that they can only finish the game if they have worked with and communicated with others. These interactions between the students can either take place in the Textchat or with help of the Itemboard.

The textchat is a tool that allows for multiple clients (students) to communicate over the server in real-time. It can be accessed via a button at the top left of the screen at any point during the game which opens a chat window as shown in figure 5.17. All students currently in the game can discuss their findings and questions in the chat.

Figure 5.17.: Textchat

The itemboard is loosely based on the concept of a whiteboard. To prevent the exchange of off-topic information or an overcrowded board full of text, it is not possible to write random text messages on the board. These issues were raised in the feedback of this project's first prototype (Tomes, 2015) and, therefore, considered and adapted. Instead players can simply pin their item information to the board, arrange the information boxes or delete them. This easy structure provides clarity and a quick overview over the information. The control is very straightforward – four spots with add-buttons (see figure 5.18) which, when clicked, draw up a list of items in the player's inventory to choose from (see figure 5.19). Once an item is selected it is pinned to the spot on the itemboard (see figure 5.20). Students can rearrange the information pieces by dragging a box to another spot. Deleting information is done by clicking the delete-button found top right of the according spot. If the itemboard is full there can easily be added another board with four spots by clicking on the extend-button found on the right side of the board (see figure 5.21).

Another way to gather information, either of general or item-specific nature, is to use the Chatbot. As described before this chat-like system generates answers

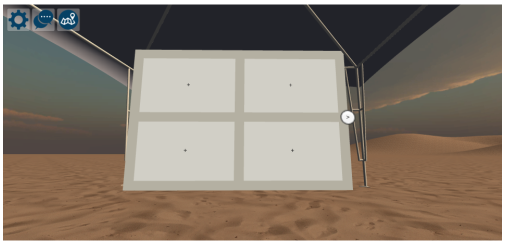

Figure 5.18.: Itemboard empty

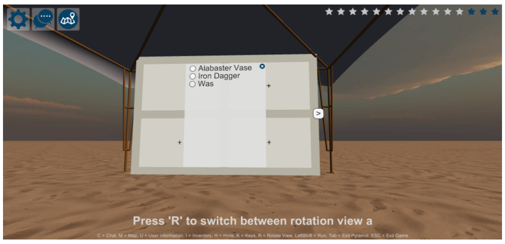


Figure 5.19.: Itemboard add item

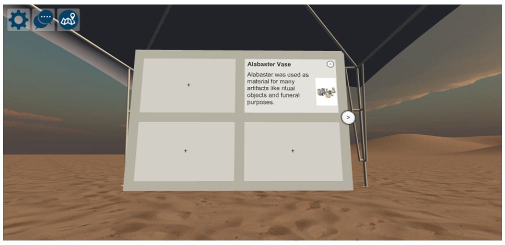


Figure 5.20.: Itemboard with item

Figure 5.21.: Extended itemboard

automatically. A very simple decision-tree chatbot was implemented. It offers several possible questions to choose from and gives the according answer and a choice of follow-up questions. The chatbot in the world is represented by a person, as shown in 5.22.

Figure 5.22.: Chatbot

Summing up, in the case of this project players have to collaborate to reach their learning goal. This is a big incentive to use one of three collaborative tools implemented in the game: textchat, itemboard or chatbot.

### 5.1.4. Learning Module: Quiz

Once students gathered all the information necessary to form the story they can take a quiz, revising all the facts learned. On finishing the quiz, they are transported into an end-scene (see figure 5.25). In this project the game ends at this point but further development might use this as starting point for another level. A quiz gives the student a sense of achievement when passing and the teacher an assessment of the knowledge base of each student.


Figure 5.23.: Add a quiz question via this Interface


Figure 5.24.: Take the final quiz

All quiz questions are saved in an XML[1]-document, a software- and hardware-independent document format used for data storage. Teachers can add questions either by editing the XML-file in a standard editor or during game-play by using the quiz button in the settings menu (see figure 5.23). There is a pool of questions for each item. When a question is needed in the final quiz or for

[1]http://www.w3schools.com/xml/


Figure 5.25.: End scene

accessing certain item information, a question is randomly picked from a bank of questions.

The quiz is, on the one hand, a kind of self-assessment as students see how well they remember the facts learning in the game. On the other hand, it gives teachers the opportunity to assess students and grade them.

Concluding, the learning module focuses on assessing the actual learning progress made in the game in form of a quiz.

### 5.1.5. Analytic Module: Logging

For analytic reasons all user interactions are documented into a log file, such as:

- start and end time of the game,
- collaboration tools chosen for communication (chat times, items added or deleted from itemboard, questions asked at the chatbot),
- interaction with items (Which item was picked up? Was there a pick-up question? Was it answered correctly?),
- quiz taken (Which questions were asked? Which were answered correctly?)

It can be useful for analytic purposes to see how students gather their information, the means of communication they prefer, how long it takes them to find items and much more. Literature refers to assessment as one of the influences on success in educational scenarios in virtual worlds. One example of assessment in virtual worlds is logging. However, while assessment can usually be done easily by the game developer it is hard for a teacher to get the information. It is, therefore, a future goal to make the information accessible to instructors, who can then analyse it. This consideration led to the development of the analytic module.

The log system is only the first prototype of its kind, therefore, improvements and extension have to be made. Currently all information is listed in each module in the XML-file. In future a clearer separation of those modules would be enhancing the readability and analysis of the log document. Moreover, more modules could be added.

Summing up, a logging system was implemented to give the teacher an overview over student behaviour in the game.

## 5.2. Alternative Scenarios

These implemented tools are applicable for countless other learning scenarios. The essence of the game of dividing the subject into small pieces of information and attaching them to items associated with or representing the part in the story, is transferable to every other subject matter or scenario. Possible teaching applications include exploring and learning about:

- cities and their sights, or archaeological sites,
- historic events (battles, discoveries..),
- personal history (kings and queens, explorers, writers, artists..),
- specific places (mining sites, farms, libraries, museums..),
- specific subject matters (medicine, sciences..), or
- new hobbies (cooking ..).

The list is endless. Whereas it is easy to imagine the above described tools in a scenario exploring a city or site, as this is basically what this game does, other ideas of the list might be more far fetched. However, walking around a kitchen exploring the utensils and tools used for certain recipes or finding certain ingredients for a dish could work. Also learning medicine or sciences by exploring a specific area in the field, finding and picking up tools needed or objects involved could be an application. The personal life of a person could be described in information pieces hidden at important places in the life of the person.

Concluding, the ideas for application of the implemented tools are endless. Moreover, the learning concepts integrated were first carefully researched and selected and secondly implemented in the modules of this game. Tools can, therefore, be similarly used in many other scenarios.

## 5.3. Summary

The Egyptian showcase scenario has an environment with multiple pyramids and Egyptian scenery to explore. There are items hidden throughout the area which have pieces of information attached that can be formed to a story. Students have to explore the virtual world to find those items, which can then be stored in an inventory. As there are different user roles which prevent them from picking up all items, students are encouraged to work together and collaborate to achieve their learning goal. They can communicate via the textchat or itemboard. There are progress stars showing how many more items have to be found. There is also a chatbot that can be questioned. Once the students found all the items they can take a quiz. To further engage with the already found items students are asked pick-up questions during the game to practise their memorization of the newly gained knowledge.

The learning concepts and influences researched in chapter 2 were considered thoroughly and implemented with care in this project as follows:
The exploratory concept including an authentic world, avatars to associate people with, a realistic first-person view into the game, experimenting and finding their own paths to learning, as well as having helping tools for exploration of the area (map, hints) were integrated. These are important aspects concerning student immersion in the game and, thus, the engagement. Moreover, the challenge-based and closely-related collaborative learning method was implemented by adding student roles, pick-up restrictions, additional pick-up questions, a maze and communication tools (textchat, itemboard, chatbot). This facilitates motivation in the game and, therefore, better learning outcomes. Other steps were taken to improve motivation in the game and to improve issues raised in the first prototype (progress stars, map, pick-up questions).

# 6. Evaluation

In order to evaluate the learning modules implemented and to see how the single tools are accepted and used, a series of tests was conducted.
There are two target groups of interest: students and teachers. In the scope of this thesis only the student view was evaluated, although two participants are studying to be teachers which might offer some insights into the other target group, as well as from a general point of view. However, the administrator (i.e. teacher) tools of the game were not formally evaluated.
Participants were divided into groups of four and asked to perform several learning tasks in the Egyptian learning world to evaluate the implemented tools, as well as assess the overall (1) immersion, (2) motivation, and (3) usability of the world. Each test session was planned to take approximately 70 minutes. Due to the variety of tools not all were focused on but participants had the choice to use them during their tasks.

The following section describes the methodology and research focus, as well as the participants and exact procedure of the evaluation. Then the results are discussed.

In this chapter "M" is used for "mean" and "SD" for "standard deviation" and the values are selected on a Likert-scale from 1 (= strongly disagree) to 5 (= strongly agree).

## 6.1. Research Focus

The requirements of these learning tools include knowledge acquisition, enhancement of the conceptual understanding, and measurement of the learning progress. These objectives should be facilitated by the use of certain teaching methods implemented in the world, (1) collaborative learning, (2) exploratory learning, and (3) challenge-based learning. The learning modules and tools

were implemented based on these pedagogical concepts. The challenging, exploratory nature of the game, as well as collaborating with others should promote not only good learning outcomes but also motivation.
Moreover, the improvement of graphics and the general look of the virtual world was aspired to, as authentic scenarios promote immersion.
The research focus, therefore, lay on these three main aspects, taken from Tomes (2015) to, furthermore, provide a comparison between the outcome of this evaluation and the one of the first prototype implemented in OWL:

1. The motivation of students, measured by factors such as loss of self-consciousness, or transformation of time
2. The usability of the developed learning tools and if the students would use them in practice
3. The immersion the students experience while they are working on tasks in the Virtual Egypt World

Sets of standardized questions regarding these three topics were combined to a questionnaire assessing the participants after finishing the learning tasks in the world.
The actual learning outcome was not part of this evaluation as short-term understanding as well as long-term memorization would have to be tested to get meaningful results.

## 6.2. Methodology

The evaluation was conducted in groups of four people at a time to stimulate a typical medium-sized learning group and make use of the collaborative tools in the game.

The international aspect of networked multi-player virtual worlds was also taken into account, as in each test group at least one person was in another city or country at the time of testing. During the tasks there was no communication between the participants other than the in-world collaboration tools. Due to the background music playing the participants were given headphones which increased the focus on the game instead of the other people in the room.

In the beginning the procedure of the evaluation was explained. Then the evaluations were conducted consisting of the pre-questionnaire, the task session, the post-questionnaire and personal interviews. The procedure is described in more detail in section 6.4.

## 6.3. Participants

The evaluation was conducted with 15 people between the age of 17 and 33 (M=26,07; SD=3,75). 5 of the the participants were male, 10 female.

The majority of the participants are students at University level (9 out of 15 participants), but there are 5 already working full time and 1 high-school student. Of the students there is a wide mix of disciplines, including software-development and business management, teacher-training, biomedical engineering, environmental system sciences, and health science. The areas of profession of the working participants are also mixed: marketing, chemistry, engineering, sales, and electronics.
7 of the participants have a bachelor's degree (BSc. or BA), 4 have a master's degree, one has a PhD, and 3 still study at in university and at school.
Regarding their prior expertise with computers most participants stated they have average or above average experience (M=3,53; SD=0,92). The results concerning their usage of MMOGs, virtual worlds and video games was quite conclusive with no high scores in the usage of MMOGs (M=1,67; SD=1,11) and virtual worlds (M=1,8; SD= 1,15), and hardy any high scores regarding computer games (M=2; SD=0,78). These results are discussed in more detail in section 6.6.

## 6.4. Procedure

Evaluations were done in groups of 4. As there was no verbal communication tool integrated in the virtual world all four could be in the same room during the evaluation. The participants were given a general overview over the procedure:

- Pre-questionnaire
- Task session
- Post-questionnaire

First the pre-questionnaire was to be filled in inquiring general information about the person and the background in computer usage and skills, as well as Egyptology.

Then the virtual world was briefly described, about as follows: *"This virtual learning world will teach you about the Egyptian myth of Osiris. There are several items hidden throughout the virtual environment with pieces of information attached. Your goal is to find and pick up as many items as possible. However, you will be given different user roles which restrict you of picking up all items yourself. Therefore, you will have to collaborate with other players to get all information about the story. Sharing information can be done via a textchat and an itemboard. Gathering information is assisted by a chatbot answering several questions, a map showing you where you currently are, your inventory of all items you have already picked up, can and can not pick up, and hints if you do not know what to do."*
Then several instructions on the process were given, referring to the learning tasks participants had to master and on controls in the world (arrows or WASD keys for walking, plus shift for running, and key shortcuts for all menu items).

Then the main part of the study started and participants were asked to stop verbal communication outside of the virtual world and start the scavenger hunt. The virtual world has background music, therefore the participants were given headphones in order to fully concentrate and immerse.

**Tasks**
The task session consisted of 6 tasks. 3 of them are for getting to know the virtual world, controls in the world and the other participants. Task 4 is the main task, consisting of finding the items, task 5 again encourages the collaboration between the players and task 6 is about the quiz.

**Task 1** Participants were asked to log into the virtual world by choosing a username and avatar, and have a look around. They were told to explore and wander around for a while to get used to the controls. They were, however, not to enter the pyramid or interact with items in the area.

**Task 2** Task 2 consisted of introducing each other in the text chat.

During these two tasks the test facilitator logged in as the administrator, assigned a different role to everybody.

**Task 3** The participants were invited to examine their user roles and see what the menu has to offer. At that point the participants should be acquainted with the controls and moving around the area, as well as the other players, their own user role, and the different options in the menu.

**Task 4** At that point the main task started. Whereas the first three tasks each took a few minutes this task was given at least 15 minutes. Task 4 asked the participants to start looking for the items that would give them information about the story. It was indicated that one of the pyramids could be entered and that picked-up items can be looked up in the inventory.
The participants then explored the environment for items while being monitored by the administrator. The general mood, immersion, and non-verbal feedback was gathered from observing the participants play.
As it was only a study with limited time the participants were asked to stop at some point, even if they had not already found all items.

**Task 5** This task consisted of sending the players back to meet in front of the itemboard to discuss their findings and information. It was suggested to use the textchat and itemboard for collaboration purposes.

**Task 6** Participants were asked to find the "finishing line" - the camels - to take the quiz, as soon as they considered themselves ready and in possession of all the knowledge necessary.

Once the quiz was finished another scene started, congratulating them on finishing the tasks.
During the test the participants were monitored by the administrator to observe their motivation, immersion, and usability problems.
Participants were then asked to take the rest of the questionnaire regarding impressions of the Egyptian world, assessment of the learning tools, the design of and communication in the world, motivation, immersion, and usability of the Egyptian world.
Afterwards a short personal interview with every participant was conducted to determine additional impressions and feedback that may not have been covered in the questionnaire, how well they think students and teachers would embrace and use virtual learning worlds, how useful they think virtual learning worlds are regarding motivation and learning success.

## 6.5. Materials

The materials described in this section, along with notes taken at the personal interview are included in the appendix on the DVD.
The questionnaires used were taken from Tomes (2015) in order to create comparable results. However, some sections were extended, as described below.

### 6.5.1. Pre-Questionnaire

The pre-questionnaire consisted of three parts, (1) personal information, (2) background on Egyptology, and (3) computer and virtual world experience. In total there were 25 questions, asking about the age, gender, occupation, knowledge, and experience with computers and virtual worlds, as well as with Egyptology.

### 6.5.2. Tasks

The tasklist, as described above, was given to each participant and read aloud or electronically communicated, to those not present, when the task started.

### 6.5.3. Post-Questionnaire

The post-questionnaire was divided into two categories: (1) the impression of the implemented world including the learning tools, as well as design of and communication in the world, and (2) a set of standardized questions on motivation, immersion, and usability. In more detail, the six sections are: (1) impressions of the Egyptian world, (2) assessment of the learning tools, (3) design and communication, (4) motivation, (5) immersion, and (6) usability of the Egyptian world.
The first part about the learning world was extended by questions about new additional features that were not present in the first prototype. The other sections are described below. Overall, the post-questionnaire had 106 questions and could mostly be answered by selecting a value of 1 (= strongly disagree) to 5 (= strongly agree) on a Likert scale.

### Design and Communication

The questions about the design and communication in the environment taken from Tomes (2015) were extended by a partial questionnaire regarding presence by Witmer & Singer (1998). Their questions consider realism, possibility to act, quality of interface, possibility to examine, and self-evaluation of performance. In total this section has 19 questions.

### Motivation

The questions about motivation were taken from Jackson & H. W. Marsh (1996). They try to measure the participant's motivation by asking about the nine dimensions of flow, as *"flow is an intrinsically enjoyable state and is accompanied by an order in consciousness whereby the person experiences clarity of goals and knowledge of performance, complete concentration, feelings of control, and feelings of being totally in tune with the performance".*
Therefore, flow has a big impact on the learner's performance in the virtual world. The dimensions are as follows (Jackson & H. W. Marsh, 1996):

- challenge-skill balance,
- action-awareness merging,
- clear goals,
- unambiguous feedback,
- concentration on task at hand,
- sense of control,
- loss of self-consciousness,
- transformation of time, and
- autotelic experience.

To test the amount of flow participants experience while completing the learning tasks, a subset of 20 questions was taken from the original questionnaire they suggest. For simplicity reasons, instead of assigning an individual weight to each of the questions, they will equally contribute to the result.

### Immersion

Questions in the category on immersion was, on the one hand, taken from Jennett et al. (2008) and, on the other hand, the game engagement questionnaire by Brockmyer et al. (2009). Jennett et al. (2008) developed a questionnaire consisting of 32 questions about immersion, 22 of which were used for this evaluation. Another 15 questions were added from Brockmyer et al. (2009) who tried to measure the engagement in games, including the concepts of presence, flow, absorption, and dissociation.

In total this section has 37 questions.

### Usability

To evaluate the usability of the environment, the standardized System Usability Scale (SUS) by Brooke (1996) was used. It consists of ten questions that can be answered with the Likert-scale from 1 (= strongly disagree) to 5 (= strongly agree). At the end, with the ratings of all participants, a score between 0 and 100 can be calculated representing the usability of the system. Hence, it results in a single number representing the overall usability of the system as the individual scores to the questions are not meaningful on their own.

To achieve comparable results to the other categories and the evaluation of Tomes (2015), who used the same system, outcomes of motivation and immersion were transformed into a score from 0 to 100 as well. To do so, for all three categories - SUS, motivation and immersion - the participants' answers were converted into values from 0 to 4. Negatively phrased questions were of course inverted. Then, the values were added for each participant and multiplied by a factor to get a result ranging from 0 to 100. For the SUS, this factor was 2,50 because there were 10 questions. Because there were 20 questions for motivation the factor is 1,25 and for immersion with 37 questions a factor of 0,675 was calculated. Lastly, the mean value and standard deviation was calculated from the individual sums of the participants.

### 6.5.4. Interviews

Notes taken from the personal interviews or written feedback given are attached in the appendix as well. As not all participants were physically present at the test sessions the use of a camera for the personal interview was refrained from.

## 6.6. Results

This section describes the results of the evaluation. It is structured into subsections on the outcomes of the pre-questionnaire and the post-questionnaire, observations made during the task sessions and results of the personal interviews. The results are presented by stating the mean and standard deviation from questions answered with the Likert scale, as well as discussing these values. Open questions are summarized or quoted, and charts represent the outcomes of some questions throughout this section.

### 6.6.1. Pre-Questionnaire

The following subsections sum up the results of the pre-questionnaire regarding the participants' experience with computers and Egyptology, as well as their expectations of the virtual world.

#### Experience with Computers and Egyptology

14 of 15 participants stated they have no prior knowledge in the field of Egyptology. The single person who has prior knowledge studies to be a history teacher, as well as had a personal interest in Egypt. 2 people had heard about the "Osiris Myth" before.

Regarding their expertise in computer usage, most participants stated they had medium (5 out of 15 participants) or above medium experience (6 out of 15 participants), 2 had below medium, 2 are experts and nobody had no experience, as shown in figure 6.1. This resulted in a mean value of 3,53 and a standard deviation of 0,92.

The distribution was about the same for internet usage with a mean of 3,60 and a standard deviation of 0,99 or 1 participant with no expertise, 5 participants with medium, 7 with above medium and 2 with best internet experience.
No participant claimed to be an expert in video-games, 2 above medium and 1 medium and the majority answered below medium (7 of 15 participants) or no expert (5 of 15 participants). This resulted in a mean of 2,00 and a standard deviation of 1,00.

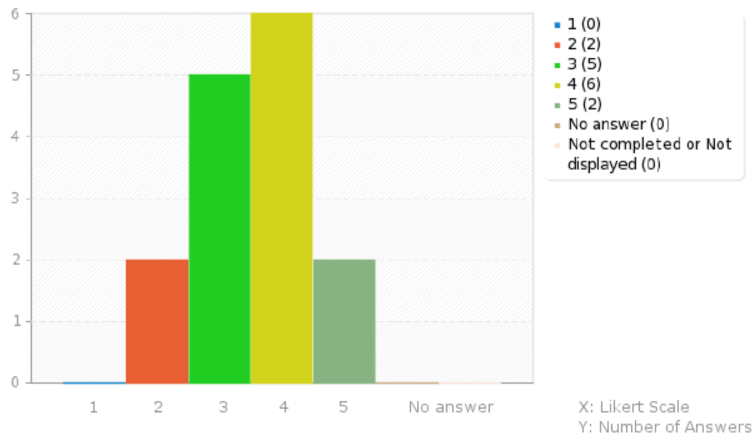


Figure 6.1.: Question:*"I am an expert in computer usage"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

Participants were very conclusive about the usage of MMOGs, virtual worlds and video-games. 10 of 15 people stated they were no experts in the usage of MMOGs, 2 below medium, 1 medium and 2 above medium and nobody an expert (M=1,67; SD=1,11).
Nearly the same can be said for the usage of virtual world environments. 9 participants claimed to be no experts, 2 below medium, 2 medium and 2 above medium (M=1,80; SD=1,15).
The participants generally do not play video-games very often, 4 said never, 6 below medium and 4 medium (M=2,00; SD=0,78). 3 participants like playing video-games above medium, 5 participants like it medium, 4 below medium, and 3 do not like it (M=2,53; SD=1,06).

If participants play video-games 5 of them play adventure games, each 4 play role-playing and action, 3 play strategy and sport (in the category other), and 2 play simulation games. Games are played mostly on laptops (by 9 participants), then smartphones or tablets (by 7 of them), and only a few on computers (by 3 participants) or consoles (by 2 of them).

Questions regarding the use of virtual worlds, if participants already had experience with them were inconclusive as 4 to 7 people did not answer the question. This confirms the above asked question if they are experts in virtual worlds, which was answered mostly no.

### Expectations

Participants were moreover asked if they saw any advantages of virtual worlds used for learning. Common answers included *"Fun"*, *"motivating"* and *"engaging"*. Three people referred to overcoming geographic restrictions and that it *"allows collaboration regardless of distances in real life"*. The *"social effect and team-working"* was mentioned a second time. Several stated learning in virtual worlds was interactive. Adjectives also used were modern, fast, easy and useful. Other advantages mentioned were that it could be used for explaining technical processes and target groups could be specified.

One person stated that *"the students have a 'real' experience of what they study and will learn easier and faster if they have a visual learning type"*. Another pointed out the virtual worlds might *"simulate an environment that is difficult to visit because it is either a historic setting or e.g. for cost reasons"*.

One participant explained he/she had never been in contact with virtual worlds for learning. Virtual earning worlds might, however, be able to convey information properly if they were well prepared.
Three people did not give an answer.

Disadvantages were listed by 9 people of 15. They included less social contact and face-to-face communication, more time spent in front of a computer and distraction. It was considered that *"being in front of the screen might be tiring"* and that the hand, eye, brain connection might suffer (*"have a bad influence"*) under slight delays in the virtual world to actions. Another person just stated that students needed a smart device or computer to use virtual worlds for learning, which might be a disadvantage.

Regarding the learning objectives and activities participants would like to use in a virtual world, which 7 out of 15 answered, quizzes and challenges, as well as question-answer-interaction were mentioned. Moreover, participants stated they wanted the world to be different and interactive every time they used it, learning by doing, to gain common knowledge, to move around in the virtual world to experience the learning subject. One person listed designing and visualization such as technical applications as 3D visualizations.

Asked if collaboration was important in learning, the answers were inconclusive as 7 said medium, each 3 said above and below medium and 1 each said important and not important. Therefore, the mean is 3 and the standard deviation 1. Regarding the interactivity of learning 6 answered above medium, 3 each important and below medium, 2 medium and one not important. The resulted mean is 3,47 and the standard deviation 1,25. A graphically rich learning environment was also rather important, 2 very important, 2 above medium, and 3 each medium and below medium, which yield a mean of 3,53 and a standard deviation of 0,99.

### 6.6.2. Task Sessions

This section discusses observations made by the test facilitator regarding handling of the controls, interaction with the tools in the virtual world and engagement and immersion in the process, as well as issues faced during the task sessions.

#### Technical Issues

There were hardly any difficulties starting the virtual world on Windows computers. In two cases during the first test session a particular internet connection seemed to take longer to connect to the PUN server than others. Using "eduroam" (on December 10th, 2015 around 5:15 pm) led to long waiting periods which was why another wifi connection of the University (tug-wpa) was used and immediately proved successful. During other test sessions at the University, as well as on private wifi connections everything worked perfectly and only a normal amount of time was needed to load and login to the virtual world.
Another issue that occurred was the use of a Mac OS X laptop. The world was not loading all graphical user interface elements accordingly which resulted in the participant not being able to log into the virtual world. In that case the participant could do the task session on another borrowed Windows laptop.

Research on the topic revealed several issues regarding the `inputfields` and `textfields` in `OnGUI()`-methods and in connection with all `Input` classes or mouse events (`MouseUp, MouseDown`) on Mac OS X. As no Mac device had been available for testing this issue was temporarily disregarded and are added to the future work section.
One participant also played the virtual world on Linux, which worked without problems, as well.

### Controls

Participants generally had some difficulties controlling the avatar in the beginning. Even though the control keys were known to them it took some adjustment time. Particularly participants who did not have any experience with computer games had problems navigating through the narrow corridors of the pyramid maze. Participants with more computer or gaming experience were fine after getting used to the controls.

### Interactions with Tools

The chat was used a lot during the whole session by all test groups. It worked fine and no issues occurred.
The itemboard was also used by all groups as a meaning of sharing information with the other players. It was not always immediately clear how to use it but the participants usually figured it out pretty quickly.
Opposed to the other collaborational tools, the chatbot was hardly used. This might be due to the fact that both other tools were particularly referred to in the tasks, while the chatbot was simply mentioned, but not explained in more detail.
The map was appreciated and used by all participants. In the first test session some errors occurred with regard to the map, which were fixed before the other sessions in order to get feedback on the working map as well.
Although the key shortcuts were written at the bottom of the screen, participants often did not seem to notice and asked for them. Moreover, the menu was not or hardly, used by the participants, as they used the key shortcuts instead.

#### Engagement and Immersion

From the monitoring point of view the participants seemed to be engaged in the virtual world and challenged to pick up more items and do well in the final quiz. The group dynamics, which are not really influenced by the virtual environment itself, seemed to play a big role, as some groups were collaborating really well, enjoyed talking in the chat and collaborating and working together, whereas other groups seemed a bit more reluctant. Everybody, however, was challenged to find more items (often the amount of items found by each person was compared) and to do well in the quiz (again the quiz score was compared and the questions talked about).

### 6.6.3. Post-Questionnaire

This section shows the results of the post-questionnaire.

One thing that became apparent when looking at the scores was that 1 of the 15 people scored quite differently than all the others. The difference is so clear that it was instantly noticeable when looking at the outcomes. Moreover, the same person showed little interest during the task session and personal interview. During the task session it was observed that the participant left to take the quiz without sharing his/her findings with the others or looking at the other players' findings. Upon addressing the lack of collaboration the person stated he/she was not feeling like collaborating and would rather have done the tasks alone. This lack of motivation and interest also affected the post-questionnaire.
This is not an uncommon situation as in every class a few students will not participate, either out of spite and rebellion, or simply because they do not feel comfortable with group work and collaboration. Solutions have to be found to integrate or motivate such students to still participate or to learn in a different way.
In this test, the test facilitator may have motivated the participant earlier to collaborate but due to monitoring everybody at the same time the lack of participation only became apparent too late.
As his/her data set is significantly different to all other participants, the mean and standard deviation for the sections motivation, immersion, and usability with and without this person were calculated to see how much one disinterested person would affect the outcomes.

Results are compared to Tomes (2015)' outcomes. However, the questionnaires differ slightly in some sections which makes a comparison not 100 percent accurate.

### First Impression

The first impression of the virtual Egypt world was it has nice touches with camels and tents, different things to see at first sight (e.g. pyramids, desert, tents) and many details. The music was good and suitable. Some participants referred to the good design, very appealing visuals, and nice 3D graphics. One person, however, said it was a simple world and looked a bit old fashioned.

Participants stated *"you become curious immediately because of glowing objects"*, it *"feels like you are in Egypt"*, and it was just as they imagined it to be. Moreover, two people mentioned they liked the collaboration and interaction with others in the world. One referred to the clear structure and the definition of the play buttons was simple to understand. Several people also remarked that it was interesting and was a *"cool way of collecting information about a new topic"*.

Asked what they liked about the world participants stated the following:

- the itemboard (*"[..] to share information"*, *"[..] was very cool so you could gather all the information of all players. Really great idea and implementation"*),
- the map (*"one would be lost without it in the pyramid"*),
- the maze (*"finding new paths in the pyramid was great fun"*),
- the glowing of the items (*"objects that have to be collected are highlighted and easy to see from a distance"*),
- collaboration (*"that others are needed to solve the quiz"*, *"interaction with other players"*),
- the clear structure (*"easy to get a quick overview of everything"*),
- the menu (*"[..] is always visible in the bottom line of the window - which makes it easy to remember commands"*),
- the virtual environment (*"everything was far enough apart and close enough together"*, *"walking around in the world and answering questions during walking around"*, *"that you can move rather freely"*),
- graphics (*"the excellent graphics"*, *"very quick response in the graphics when the avatar turns"*), 3D effects, objects, clouds

The question what participants did not like often referred to some implementational bugs, such as the map did not always work properly (which was fixed after the first test session), question panels closed involuntarily (also fixed after first session) and that the rotation view was blocked after the chat, which was intentionally done whenever a panel was open.
Other comments included that there was no signal for new messages in the chat, running was slow, the font size was a bit too small in the questions, the colouring of text sometimes made it hard to read, it was a long way to the pyramids without anything happening. One person commented that the first few minutes were hard to get started but one got into the virtual world intuitively with ongoing game-play. Another participant stated that it was not clear how information could be pinned to the itemboard which was why sometimes information was deleted unintentionally.

Asked for suggestions for improvements people listed the following aspects:

- improving the chat (*"indication when a message was sent in the group chat"*, *"closing the chat with 'x'"*, *"moving while chat is open"*),
- regarding the map (*"see on the map which pyramid can be entered"*, *"localization where player is on map in real-time"*),
- smoother navigation (rotation),
- letters could be in black instead of white.

### Assessment of the Learning Tools

Visually identifying the items by its glow was very important (M=4,40; SD=1,06) as shown in figure 6.2.

Relatively important were the itemboard (M=4,21; SD=0,80), the quiz (M=4,13; SD=0,99) and the map (M=4,00; SD=1,15), as shown in figure 6.3. The frequent use of these tools was, moreover, observed while monitoring the sessions.

The inventory was still pretty important (M=4,00; SD=1,13), as well as the pick-up questions (M=3,93; SD=1,22) and having different roles (M=3,93; SD=0,88). The chatbot, however, was not very important (M=3,55; SD=1,29), as were the progress stars (M=3,45; SD=1,13). This coincides with the observations during the sessions, as the chatbot was hardly ever used and the stars were sometimes not even noticed.

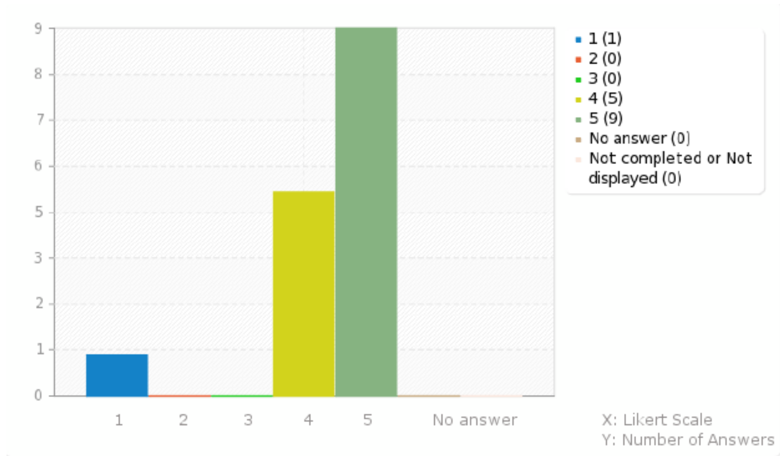


Figure 6.2.: Question:*"I think that visually identifying the items (by making them glow) is important for the experience"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

When asking the participants which features they liked, most of them listed the chat, the itemboard, the map and the quiz. Many stated that they liked the interactions with items and picking up items. They, moreover, liked the statues of the gods and artefacts, and the realistic scene. The maze in the pyramid and the inventory were also mentioned. One person stated the chatbot was very good.
Upon asking them what they did not like, very minor comments were made. Participants mentioned the pyramid was rather confusing and complex, that you could not navigate while the chat was open, the controls were a bit tricky at first. Moreover, it was mentioned that the purpose of the progress stars and the chatbot was not realised for a long time.
There were no major suggestions for improvement.

### Design and Communication

Most participants thought the environment was very interactive, the system allowed collaboration (M=4,14; SD=1,10; as shown in figure 6.4), made collaboration easy (M=4,13; SD=0,83) and discussions were relatively easy (M=3,93; SD=0,73).

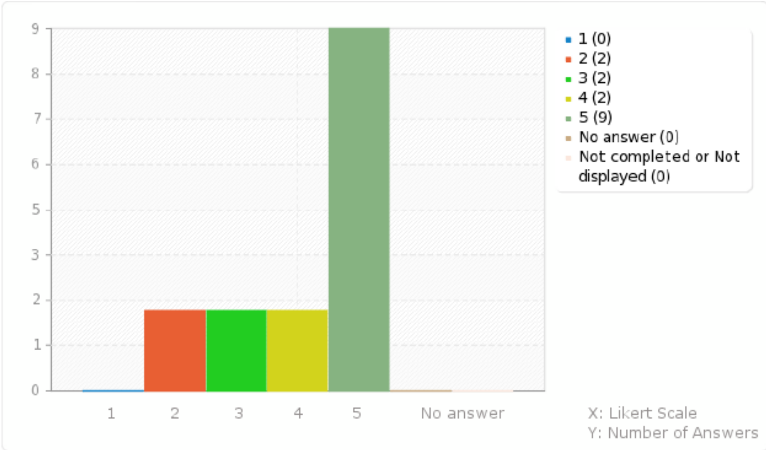


Figure 6.3.: Question:*"I think that the map was important for the experience"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

The system was easy to use (as shown in figure 6.5), going through the tasks was fun 6.6 and participants learned something new.

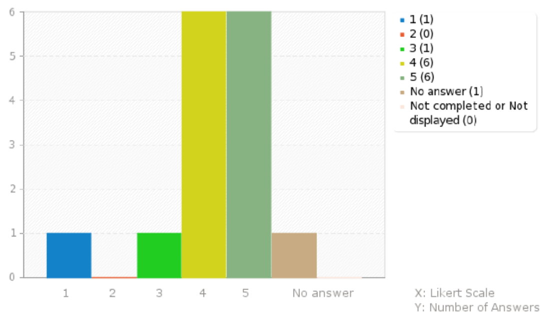


Figure 6.4.: Question:*"The system allowed collaboration"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

The possibility to act was mediocre or slightly above with respect to controlling the events, responsiveness of the environment to actions, anticipating what would happen next in response to actions performed.

Similarly the realism of the world was relatively good but not perfect. *"How natural did interactions seem"* and *"how consistent was the virtual world with the real world"* were answered slightly above mediocre.

Self-evaluation of the performance was rather good as participants adjusted to

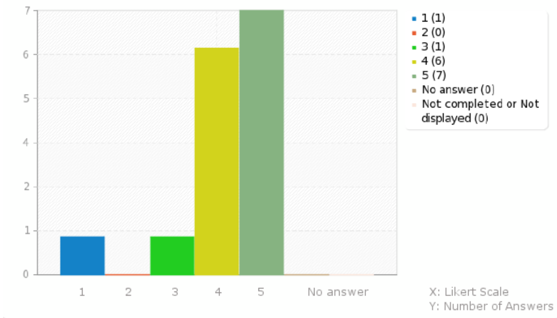


Figure 6.5.: Question:*"The system is easy to use"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

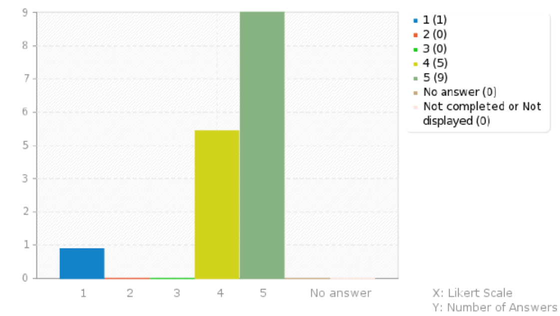


Figure 6.6.: Question:*"I had fun going through the tasks"*. Answers with the Likert scale from 0 (=strongly disagree) to 5 (=strongly agree).

the virtual world experience with a mean of 4,36 and the proficiency in moving and interacting with the world at the end of the experience was evaluated with a mean of 4,07.

## Motivation

On a scale form 0 to 100 the mean score in the category "Motivation" was 65,67 with a standard deviation of 19,03. The sum of each person's score was multiplied with the factor of 1,25 as this section has 20 questions. From these results the mean and standard deviation was calculated.
The mean without the particular participant mentioned in section 6.6.3 is 69,46 and the standard deviation 12,30. It can be seen that both values are significantly better without this one data set.

However, the overall motivation could be better. Looking at the single questions some improvements became apparent. The aim behind the virtual world should be 100 percent clear, however, was only mostly clear. Participants did not always know exactly how well they currently did and some did not feel absolutely competent enough. This coincides with some feedback that some participants did not get the meaning behind the progress stars, which would have shown the progress, had slight problems getting used to the controls, and did not fully understand the goal of the virtual world after the instructions. Probably clearer instructions and a better overall description of the virtual world should have been given beforehand. Other participants liked the stars and compared their progress with help of them.

There were also some findings that people generally liked the virtual learning world. Most participants had fun and enjoyed the experience a lot (shown in figure 6.7) and it left them feeling great. A lot of positive feedback was given regarding the challenging and collaborational nature, and participants even wanted more collaboration and dependence on other players.

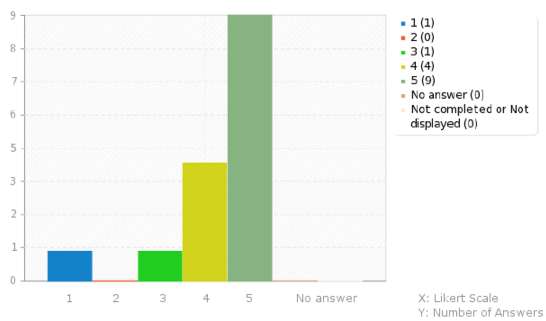


Figure 6.7.: Question:*"I really enjoyed the experience"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

Compared to Tomes (2015)' outcomes in this category the motivation using this new prototype was slightly better, as her mean was 63,68 with a standard deviation of 13,47. As the story of the virtual learning world and the learning tools were mostly the same this is not surprising. The slight improvement might stem from the new features such as the map and progress stars showing the progress, or better graphics and controls.

As motivation is closely linked to the immersion in the world, the results of the next section might have influenced the score of the motivation.

### Immersion

The mean regarding the immersion in the world is 48,19 with a standard deviation of 12,44. Without the outstanding dataset the mean is 50,19 and the standard deviation 10,12. This results are again scaled from 0 to 100 with the factor 0,68 as it were 37 questions.

The question how immersed the participant felt was answered with 8 (on a scale from 1 to 10) by 7 participants, 9 and 10 by each 2 participants and 7 by 3 participants. Only one person chose 4, which again was the particular participant mentioned above. While participants generally felt engaged in the tasks and liked doing them, they did not feel part of the world, as shown in figure 6.9. All questions regarding the awareness of their surroundings, the controls, detachment from the outside world, forgetting about their concerns etc. were answered slightly below best, sometimes medium.

So even though the graphics and imagery was also evaluated positive, as well as the tasks, participants were not really immersed, as shown in figure 6.8. This may stem from the fact that they were in an unnatural "testing" situation, they did not exactly know what they should be doing at every point, or used the world for the first time and thus had to get used to the controls. This is confirmed by the feedback participants gave, stating they needed some time getting used to the controls and it took a lot of their concentration handling the avatar. Moreover, they remarked on not knowing what to do at times. Another reason might be some technical issues, such as the map for the first group. As the tasks were announced to them after finishing the last task or after a certain time, they might not have gotten enough chance to get fully immersed in the world.

Tomes (2015)' results in this section are, again, quite similar (M=50,66; SD=11,42). The results are very similar as both evaluation had the same situation interrupting players with new tasks and limited time. It should not, however, stem from insufficient graphics as participants generally approved of them, as shown in figure 6.10.

### Usability

The usability questionnaire contained 10 questions and was scaled from 0 to 100 with the factor of 2,50. The results regarding the usability of the world were

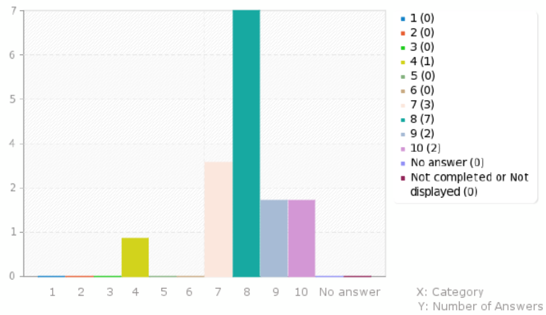


Figure 6.8.: Question:*"How immersed did you feel"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

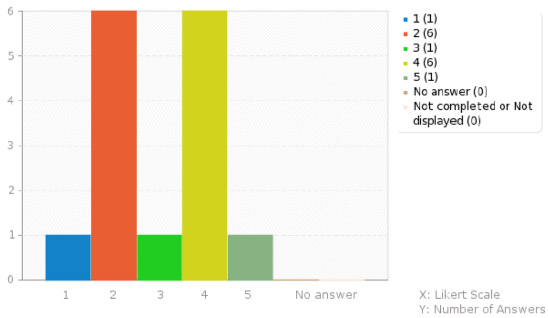


Figure 6.9.: Question:*"I still felt as if I was in the real world whilst playing"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

very good with a mean of 78,50 (SD=17,69) and omitting one dataset the mean even was 82,32 (SD=10,07). This clearly shows that the user acceptance of the environment was very good. The small deviation, moreover, shows that most people were in agreement.

Participants claimed the system was easy to use, they did not need the assistance of a technical expert, the various functions were well integrated (as shown in figure 6.11) and they thought most people would learn to use the system very quickly (as shown in figure 6.12).

Compared to Tomes (2015) this category performed significantly better, with her mean being 65,28 and standard deviation 17,70. This might result from the fact that the Unity world was very easy to handle. No server has to be started and the world is an executable file that simply has to be started.

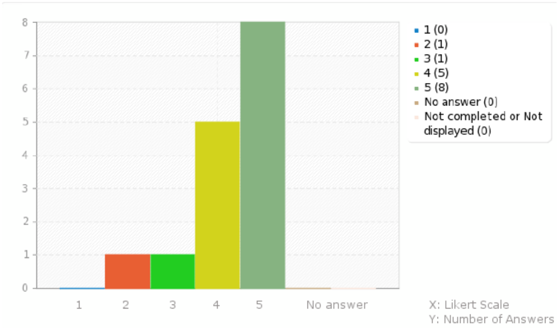


Figure 6.10.: Question:*"I enjoyed the graphics and imagery of the world"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

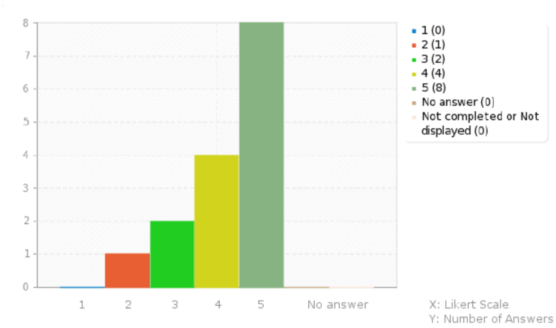


Figure 6.11.: Question:*"I found the various functions in this system were well integrated"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

### 6.6.4. Interview

In the personal interview participants were asked if there was anything they wanted to add in addition to the questionnaire. Moreover, they were asked if they thought virtual learning worlds like this were beneficial to the student motivation, as well as learning progress. Lastly the question was raised if students and teacher would accept and actually use such worlds.

The general opinion was that the world would be accepted very well by students, and probably well by younger teachers. Moreover, everybody agreed that the Egyptian learning scenario was a good fit for primary school or even 10 to 15-year-olds, that worlds like this would make classes more fun but should be used in addition not replacement to conventional classes. Feedback stated that learning effectiveness was good in a virtual learning world like this and the

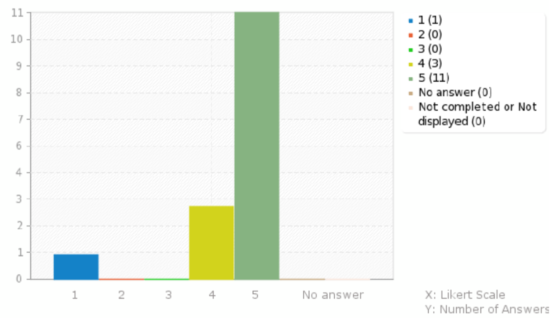


Figure 6.12.: Question:*"I would imagine that most people would learn to use this system very quickly"*. Answers with the Likert scale from 1 (=strongly disagree) to 5 (=strongly agree).

motivation very good. It was mentioned how motivational and challenging the idea of finding piece after piece of information was and that students would start pushing themselves to find more.
Everybody really liked the collaborative nature of the virtual world and remarked on it, as it was fun, engaging and challenging. Also the itemboard was commented on as it was very useful to gather all the information.

It was mentioned that different learning types were addressed, that learning-by-doing was positively used, and the visual senses were appealed to. Even the effect that students not only learn what was told in the information pieces but, additionally, what the surroundings and the artefacts looked like, in this case for example how a pyramid looked from the inside, etc.

With regard to controlling the avatar, and also the other key shortcuts and tools of the world, some difficulties existed in the beginning. One group suggested a kind of introduction to the features, comparable to an Android quick tutorial screen.
Also the description of the aim of the world should be focused on more and may be described in more detail or be integrated in the world.

Regarding the textchat some suggestions were made. First, when the chat window was closed there was no way of noticing new messages arriving. Therefore, some kind of signal announcing new messages might be helpful. Secondly, as described in the implementation section, the "WASD" controls were enabled while the chat window was open, but the "X"-closing-mechanism, as well as the rotating view were disabled. Participants remarked on moving around a little while typing, although there were no negative remarks it was

noticed as peculiar.
However, the disabled rotation and closing of the chat were noted negatively. That the chat was not closable in the same way all other panels were closed ("X") irritated several participants. Some participants, moreover, suggested leaving the chat window open during the whole gaming session and enabling the navigation while the chat was open, which might be another solution to seeing new messages arrive.
Moreover, one person mentioned the positive addition of a voice chat.

A disadvantages that was mentioned was that creating such a world was time consuming but only covered very little content compared to the effort. Moreover, it was said that teacher might only use it with as little effort and work as possible. One or two sceptics remarked that learning in virtual worlds was less social and therefore pedagogically not valuable. It might be used to learn new skills or gain extra knowledge but it should not be used in class.

The new features added to this prototype were unknowingly remarked on. The pick-up questions were very useful as the memorization effect was improved by multiple occurrences of the questions. The map was also useful as *"finding the way through the maze would have been impossible otherwise"*.

Participants saw many applications of the learning tool implemented in this world, such as physics, astronomy, biology, science, geography, and history.

There were great suggestions for future work, such as focusing even more on collaboration (players need help from others to enter the pyramid, etc.), rewards or a high score to make it more challenging and chat notifications.

## 6.7. Summary

Summing up, an evaluation with 15 participants was conducted. It consisted of a pre-questionnaire, the test session and a post-questionnaire. Everybody had sufficient computer and internet skills, however not too many people were regularly using games and virtual worlds. They, however, expected virtual worlds to be motivating and good for collaboration.

There were some technical bugs during the first test session which were fixed for the following three sessions. Some recommendations were given regarding features in the game, such as the chat.

Most of the features were accepted positively. Collaboration worked well and was easy to use. The design was much liked, with the graphics and artefacts especially mentioned.
Generally the participants were engaged and had fun completing the learning tasks and collaborating with others in the world to do so.

The results of motivation were relatively good but could be improved. Immersion was pretty low which may be traced back to the interruptions and limited time during the tasks. The section usability was evaluated very well which shows that the world was accepted well and easy to use and understand. Regarding usability this prototype significantly improved over the first prototype implemented in OWL, as shown in table 6.7.

| Category | Tomes prototype | This prototype |
|---|---|---|
| Motivation | M= 63,68; SD=13,47 | M=65,67; SD=19,03 |
| Immersion | M=50,66; SD=11,42 | M=48,19; SD=12,44 |
| Usability | M=65,28; SD=17,70 | M=78,50; SD=17,69 |

Concluding, the Egyptian world was accepted very well. The world and the pyramid maze were very well used for exploring. The graphics and models were generally approved of. The collaborative nature of the game and the challenging aspects were approved and promoted the fun, motivation and engagement in the game.

# 7. Lessons Learned and Outlook

This chapter will summarize the lessons learned during the different stages of this thesis, the literature research, the implementation and the user evaluation. It will list ideas for future work, as well as give an outlook for future projects in this field.

## 7.1. Theory

Research done on the theoretical background of student motivation, learning and teaching methods, educational digital games and virtual worlds used for educational purposes offered endless theoretical literature, as well as, studies and findings.
There are some concepts that are found to be better for learning outcomes, such as active learning and collaborative learning, instead of passive learning techniques. Many of these concepts can be connected and used together, such as for example exploratory learning and challenge-based learning.

There are several studies of digital games and virtual worlds used for educational games which show that they are, in fact, motivational for students. However, the beneficial nature of games regarding the learning effectiveness has yet to be proven, as findings are controversial in this respect. Aspects that had promising results include

- feedback,
- rewards, and
- learning instructions.

What many games have in common is that students are motivated and engaged. Virtual worlds usually contribute to immersion in the game and achieving a flow state which in turn is good for the learning progress as well as motivation.

Due to the controversial outcomes, there is no universal guide for developing successful educational games. However, researchers agree that they have a lot of potential, especially virtual worlds are particularly suitable due to their interactiveness and possibility for collaboration, hence educationalists and developers should further improve their cooperation to create the perfect game-based virtual learning world.

## 7.2. Implementation

Learning and using Unity was relatively straight-forward. There are countless official video tutorials[1] on every aspect of Unity and game examples by the Unity community[2] who, moreover, offer a forum and live video-streamed learning sessions[3]. There are also many very good unofficial example tutorials by Unity-users on YouTube[4]. There is also a documentation and scripting manual[5] to everything needed in Unity.

During the implementation of the learning environment a few difficulties arose, as discussed in section 4.3. Moreover, several implementational additions became apparent during implementation, as mentioned in the chapter 4.

The created world was tested in the 3D environment of the HIVE[6] at Curtin University, Perth, Australia. It can, on the one hand, be shown on a cylinder screen as it is or, on the other hand, be enhanced by some scripts to be viewable in 3D. A presentation was given at the Curtin HIVE demonstrating a simple version of the environment in 3D. Unfortunately, input detection was not yet supported which is why the menu, key shortcuts, chat, chatbot and all functionality with keyboard input had to be omitted. This feature might however soon be implemented by the team of the HIVE.

[1]Unity tutorials: https://unity3d.com/learn/tutorials
[2]Unity community: https://unity3d.com/community
[3]https://unity3d.com/learn/live-training
[4]YouTube: http://youtube.com
[5]Documentation: http://docs.unity3d.com/Manual/index.html
[6]HIVE at Curtin University: http://research.humanities.curtin.edu.au/projects/hive//

## 7.3. User perspective

The evaluation showed that this prototype generally improved over the first prototype implemented in OWL. The learning tools were overall well accepted and used. Graphics of the world were approved and the controls were relatively sufficient. The mechanisms of controlling the avatar worked rather well even in the pyramid. To improve the usage of controls even more, a demonstration of the controls when starting the virtual world would definitely help. A description of the game's goals should also be focused on even more.

Regarding the motivation and immersion in the world, the results were quite similar to the first prototype in OWL. However, personal interviews and observations during the game sessions showed that users were motivated and challenged quite a lot. Improvement is these sections is needed. The results regarding usability were better than for the first prototype which shows that the system is easier to use than the prototype in OWL.

Participants recommend the game for primary school or 10-15 year olds. They see games like these as good addition to the conventional classes as they are motivation and fun. Learning new material via games like this is also very well possible, according to the test users.

# 8. Conclusion and Outlook

New technology-enhanced learning approaches will continue to emerge. The virtual world developed in this thesis provided an example of how immersive learning and collaborative, exploratory and challenge-based learning games can be developed. The VLE tools offer many advantages compared to conventional teaching techniques, such as exploring an environment regardless of geographic or content-related constraints, collaborating with people from around the world and offering a more immersive way of learning than ever before. The importance of adapting to new learning technologies and tools is recognised by educational researchers, practitioners, and software designers, and will keep rising. There were several lessons learned throughout the process of literature research, prototype implementation and evaluation of the Egyptian scenario, which are described above.

The goal to revise and redesign educational activities and processes in an immersive, virtual learning environment, the implementation of a set of learning tools for Unity which enabled and supported these learning activities and the creation of an exemplary Egyptian virtual learning world in Unity to showcase these tools, was met.

Summing up previous sections, the following tools were successfully implemented: pieces of items that have information panels attached can be placed in the game area and picked up by students, students have an inventory of picked-up items and an overview of items yet to be picked up, students get assigned roles with pick-up restrictions, support tools (map, hints, progress/gamification stars), collaborative tools (text chat, chatbot, itemboard), quiz, logging of actions, administrative tools (managing of items, roles and quiz) and a settings menu to access some of these features. The tools implemented can be reused in other scenarios. As showcase scenario an Egyptian learning environment was created including a desert game area, a pyramid with a maze and the tools mentioned above.

The objectives (1) knowledge acquisition, (2) enhancement of the conceptual understanding, (3) measurement of the learning progress were satisfied, by collecting items and their information, thus assembling the story and gaining an understanding of the subject. Lastly, the learning progress was measured by taking a quiz at the end of the game. The objectives were facilitated by the use of certain teaching methods: collaborative learning, exploratory learning, and challenge-based learning. The collection of items in the Egyptian game area emphasized the exploratory nature of the game, while the roles, restrictions and pick-up questions presented challenges for students. Supporting the communication and game progress are several collaborative tools.

The created world was, moreover, tested in the 3D environment of the HIVE at Curtin University.

Overall, emphasis lay on the replication of the Egyptian learning world of Tomes (2015) in Unity. Further focus lay on the good integration of the learning concepts collaborative, exploratory and challenge-based learning.

The evaluation conducted with 15 participants resulted in a general approval of the environment and games used as learning tool. Graphics and controls got better feedback than Tomes (2015)' prototype, as well as the overall usability of the system which leads to believe that the features were better usable and Unity better suitable for interactive worlds like this.
Motivation and immersion in the game were about the same as in the evaluation of Tomes (2015). Except for a few technical points (for example integration of Mac OS) and the wish for a more detailed description of the game and demonstration of the controls beforehand no negative feedback was raised. There is more work to be done on the instructor side of the project. There is no detailed feedback, as this was not evaluated, but future improvements include:

- Addition of new items
  This is the main flaw of this project, as currently no new items can be added during game-play. This stems from the fact that Unity does not provide tools for dynamic integration of game objects, such as resizing the object, and placing or dragging the object in the environment during game-play. Therefore, it was out of the scope of this project to implement this tool.
- Dynamic management of roles
  Currently there are four roles. Although roles can easily be added in

the XML-file and will then be automatically displayed in the game, an interface for adding, editing and deleting of roles could be implemented.

- Extended question management
  Currently new questions can be added via an interface in the instructors menu but there are only multiple choice questions available. More question type such as open text-based questions could be introduced.

Although instructors still need knowledge of Unity to create a learning world, the implemented tools make creation easier. As the evaluation showed game-based virtual learning scenarios are approved by students and further research and development on this sector should, therefore, be encouraged.

# Appendix

# Appendix A.

# DVD Content

The following content can be found on the DVD attached to the printed form of this work:

- PDF version of the thesis
- Development
  - Developed Unity software
- Evaluation
  - Materials
    - Pre-Questionnaire
    - Task-List
    - Post-Questionnaire
  - Test Sessions
    - Notes of personal interviews
  - Results
    - Statistical evaluation of the questionnaires including all text answers

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