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Serious Heritage Games

Playful Approaches to Address Cultural Heritage

DISSERTATION

zur Erlangung des akademischen Grades

Doktor der technischen Wissenschaften

eingereicht von

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to the Faculty of Informatics
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Erklärung zur Verfassung der Arbeit

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Abstract

There is no doubt that digital games are part of our culture as much as books, movies and other forms of media. Video games have historically reflected technology's cutting edge of technology and constantly lead to new developments in the fields of computer graphics, game design and innovative storytelling. Today's generation of "digital natives" see video games as an integral part of their lives and have adjusted their brains to the interactivity and speed of new media. These cognitive style changes cause a conflict of generations that also comes to light in our educational system. Learners have changed from being passive observers to active participants. In fact, games have always been a powerful mediator for learning and the novel field of *serious gaming* is getting more and more established in general public and provides new ways of communicating knowledge within a game-like environment. In contrast with typical learning games, serious games cover topics outside of classical education. However, when it comes to games that are not primarily targeted at entertainment, people tend to perceive those games as boring. In addition, games are a very young phenomenon that still struggles for acceptance as a form of culture, commonly perceived as a child's medium.

We can see that over the last years many non-traditional topics have been covered within serious games. The use of games to support cultural heritage purposes has been less well considered. To fill this gap in research, this PhD thesis investigates the the usage of serious games for cultural heritage purposes. We do belief that games have the power to reflect, and thus teach culture and cultural heritage issues to some degree. We have designed and evaluated two *serious heritage games* that foster an understanding of cultural heritage. The first one, *ICURA*, is targeted at intangible artifacts of cultural heritage and fosters an understanding of contemporary culture, language, rules of behavior and etiquette of a specific country. The second one is called *ThIATRO* and communicates concepts of art history to raise the interest in museums and cultural heritage in general. Both games were evaluated to check the learning outcomes. By this means, we investigate new ways to raise children's and adults' interest in their cultural heritage and present research about effective ways to integrate game elements into cultural heritage learning scenarios. We hope that this PhD thesis may help to overcome the common misconception of games being perceived to solve no cultural or social function and to establish games as an accepted form of culture.

Kurzfassung

Digitale Spiele sind neben Literatur, Filmen und anderen Medien zweifellos ein fixer Bestandteil unserer Kultur. Aus historischer Sicht haben Spiele immer die neuesten Trends in den Bereichen Computergrafik, Game Design und innovativen Erzählstrukturen vorgegeben. Die heutige Generation der „Digital Natives“ passt sich der Interaktivität und Geschwindigkeit digitaler Spiele an und verändert dadurch ihre Denkmuster. Diese Veränderung führt zu einem Generationenkonflikt, der sich auch auf unser Bildungssystem auswirkt. Lernende wollen keine passiven Beobachter mehr sein, vielmehr werden sie zu aktiven Teilnehmern. Spiele waren immer leistungsfähige Werkzeuge zur Wissensvermittlung. Der Begriff „Serious Games“ (etwa „ernsthafte Spiele“) verbreitet sich schnell als neue Möglichkeit Wissen in einer spielerischen Umgebung zu generieren. Im Gegensatz zu gängigen Lernspielen behandeln Serious Games Themen, die im gängigen Unterricht nicht (oder nur am Rande) behandelt werden. Allerdings werden Spiele, deren Hauptzweck nicht gänzlich der Unterhaltung dienen, meist als langweilig eingestuft. Zudem sind digitale Spiele immer noch ein sehr junges Phänomen, welches häufig als kindisch abgetan wird und somit um kulturelle Akzeptanz kämpfen muss.

In den letzten Jahren wurden viele außergewöhnliche Themen in Serious Games behandelt. Hingegen wurde die Verwendung von Spielen für das Lehren kultureller und kulturhistorischer Fakten weitgehend außer acht gelassen. Um diese Forschungslücke zu füllen, beschäftigt sich die vorliegende Dissertation mit digitalen Spielen, die sich mit Themen des kulturellen Erbes auseinandersetzen. Wir sind der festen Überzeugung, dass Spiele ein Spiegel unserer Kultur sind und somit für die Vermittlung kultureller Inhalte prädestiniert sind. Im Rahmen der Dissertation wurden zwei „Serious Heritage Games“ implementiert und evaluiert, die das Verständnis für unser kulturelles Erbe fördern sollen. Ersteres, ICURA, vermittelt Informationen über immaterielles kulturelles Erbe und fördert das Verständnis für kulturelle Regeln und Verhaltensweisen eines bestimmten Landes. Das zweite Spiel, ThIATRO, kommuniziert kunsthistorische Konzepte und soll das Interesse des Spielers oder der Spielerin an Kunst und Kultur stärken. Beide Spiele wurden einer Evaluierung unterzogen, um den Wissenszuwachs der Spieler zu testen. Auf diesem Wege werden neue Möglichkeiten der Wissensvermittlung untersucht, die das kulturelle Interesse Jugendlicher und Erwachsener gleichermaßen wecken sollen. Wir präsentieren weiters aktuelle Forschungsergebnisse zur effektiven Integration spielerischer Elemente in digitalen Lernszenarien. Dadurch hoffen wir digitale Spiele als akzeptierte Kulturform integrieren zu können und die falsche Annahme, dass Spiele keinerlei kulturelle oder soziale Funktion erfüllen, zu überwinden.

Contents

CHAPTER 1

Introduction and Motivation

"We are fortunate to find ourselves at the beginning of something new and powerful." (Mark Prensky, 2004)

Games have become an integral part of today's culture. In his groundbreaking study from 1930, "Homo Ludens", Dutch cultural theorist Johan Huizinga noted that play is an essential component of all human culture and its nature of content is directly linked to poetry, art, religion, and other cultural elements [Huizinga, 1938]. Especially among those, who grew up with digital media, virtual worlds and video games are as much a part of our contemporary culture as books and movies. Mark Prensky refers to this generation as "digital natives" [Prensky, 2001b], who see computers as a friend that supports their daily lives. Technology is getting more and more important for our all lives and we are spending a huge amount of time dealing with computers, mobile phones and, of course, games. According to the Entertainment Software Association, the average game player in 2011 is 37 years old and has been playing games for 12 years [Entertainment Software Association, 2011]. Globally, gaming is big business, with a market worth an estimated $50 billion in 2011 and a demographically diverse audience with an even gender split [Henson and Birchall, 2011]. To illustrate the importance of video games to our younger generation, game designer and games researcher Jane McGonigal noted that the average person today, in a strong gamer culture, will have spent 10.000 hours gaming by the age of 21. For children in the USA, this is the exact amount of time you will spend in school from 5th grade to high school graduation if you have perfect attendance [McGonigal, 2010]. Digital games have experienced a dramatic increase in popularity and have historically reflected technology's cutting edge, leading constantly to new developments in the fields of computer graphics, game design and innovative storytelling [Eagle, 2009].

However, gaming is by far no longer a phenomenon dependent only on age. Already Huizinga stated that there is the wide misconception to regard games as pure entertainment for "adrenaline fuelled pursuits of teenage boys" [Huizinga, 1938]. He is referring to card- and board-games but in principle the situation has not changed with the emergence of digital games.

This misconception causes a bad reputation in the wide public. Whenever games are mentioned on the media, they are mostly linked to negative topics. For some people, games are even the main reason for aggressive behavior.

"Digital immigrants", referring to those who did not grow up with digital media, often see technology as something to be feared and tolerated [Prensky, 2001b]. Michael and Chen sum up these fears about computer games as "the most recent threat of Western civilization." [Michael and Chen, 2005]. Despite all these alleged bad sides of computer games, they imply a huge potential besides pure entertainment that is recently a fundamental topic of scientific research. It is well known that games are a powerful learning medium [Rieber, 1996]. James Paul Gee posed the compelling question: "Why are young people willing to put so much time and effort into learning to play extremely complex video games?" [Gee, 2003]. In his opinion games present the learning content in a meaningful and motivating way that compels the player to actively deal with the information. In the same context, Michael Zyda coined the term "collateral learning" - learning that occurs through mechanisms other than formal teaching [Zyda, 2005]. Their popularity makes them an ideal medium for educational purposes, no matter which topic or target group they are aiming at. However, learning games still struggle for acceptance. When it comes to games that are not primarily targeted at entertainment, people tend to perceive those games as boring [Bellotti et al., 2009]. Another misconception is that play is the opposite of work and thus can never be serious at all. The main reason for the public misconception may be the wrong integration of learning content into a computer game. Instead of creating boring educational add-ons, information should be well integrated into the game logic [Bellotti et al., 2008a]. A lot of research has been done to understand what it is that makes games so motivating and how learning content is integrated to cause an intrinsic learning process (see Chapter 4 for examples). Intrinsically means that the motivation is driven by an interest or enjoyment in the task itself rather than relying on any external pressure.

As a matter of fact, today's generation of "digital natives" experiences cognitive style changes and adapt their brains to the speed and interactivity of digital games. These style changes cause a conflict of generations that also comes to light in our educational system. According to Mark Prensky, "we are working hard to educate a new generation in old ways, using tools that have ceased to be effective" [Prensky, 2001a]. He further says that education in school or corporate training is largely non motivating to the games generation and provides hardly any intrinsic motivational factors. Prensky is referring to a conflict of generations that causes an ineffectiveness of our educational system. To overcome these shortcomings, he proposes constructivist teaching methods that foster an active learning process rather that passive teaching lessons. And as a key to success he supposes games in all variations that are carefully integrated in the lessons to support the educator's work. Mark Prensky summed up the possibilities of digital game-based learning in one sentence that was also inspiring for writing this thesis:

> *"[...] there is no reason that a generation that can memorize over 100 Pokemon characters with all their characteristics, history and evolution can't learn the names, populations, capitals and relationships of all the 101 nations in the world. It just depends on how it is presented."* [Prensky, 2001b]

Based on Prensky's quote, we define the first motivation of this thesis:

Motivation 1: Today's learners adjusted their brains to the speed and interactivity of new media. They are retraining their brains to think in new ways, antithetical to old ways of thinking. And this causes an educational problem. For future education it is crucial to adapt to these changes and find ways to create active and motivating learning scenarios.

The educational power of games has been proven many times (see Section 5.1 for examples). Most digital game-based learning applications cover traditional topics such as biology, chemistry or physics that benefit from the visual power of 3D virtual worlds. The so called *serious games* denote a novel phenomenon that investigate games with a purpose other than pure entertainment. In contrast with typical learning games, serious games widen the thematic range and cover topics outside of traditional education. They don't need to have a defined learning outcome and go beyond traditional modes of teaching and learning to reach a wide audience. Michael and Chen describe them as tools that "use the artistic medium of games to deliver a message, teach lessons, or provide an experience" [Michael and Chen, 2005]. Over the last years, many non-traditional topics have been covered within serious games, such as therapy, medicine or military issues. Despite this fact, there is still the common misconception of games being perceived as childish medium. As British researcher James Newman states, games struggle for acceptance because they are perceived to solve no cultural or social function [Newman, 2004]. This common misconception provides the initial point for defining the second motivation of this thesis:

Motivation 2: Games are perceived to solve no cultural or social function. Research about the possibilities of serious heritage games may help to overcome these misconception and to establish games as an accepted form of culture.

Games are capable of reflecting culture because they are objects produced and played within culture at large [Salen and Zimmerman, 2003]. This thesis takes this statement as basis to investigate how game design can influence our views on culture itself. Digital media have the power to foster the understanding of our cultural heritage in ways that written text or images will never achieve. The advances in computer graphics enabled researchers around the world to reconstruct ancient places, revive lost cultures or digitize precious artworks. With the rise of the Internet, novel ways to share and access cultural heritage artifacts were created. And with the popularity of digital games we are facing next steps to communicate our heritage to a curious generation - a generation that is next in line to carry out high-quality preservation efforts. Otherwise we are running risk of losing precious cultural assets. The area of of cultural heritage and games was widely untouched by researchers so far. According to Anderson et al., the widespread use of "gaming for leisure purposes has been well documented, the use of games to support cultural heritage purposes, such as historical teaching and learning, or for enhancing museum visits, has been less well considered" [Anderson et al., 2010]. These games are called *serious heritage games*. We can see that some recent virtual heritage projects lack interactivity and innovative storytelling techniques to capture their target audiences' enthusiasm.

Serious heritage games are a novel approach to augment those applications with challenging and motivating elements, but little research has been done to find best-practices on how to integrate game elements into cultural heritage learning scenarios. This thesis attempts to fill this gap in research:

Motivation 3: New methods of presenting the artifacts of our cultural heritage are developing in a changing world, and professionals need to adapt to these changes. This also calls for new ways of raising the interest of children and young adults in their cultural heritage. Research about effective ways to integrate game elements into cultural heritage learning scenarios may help to capture the target audiences' enthusiasm.

In general, our cultural heritage is divided into two groups, tangible and intangible artifacts: The first one mentioned covers objects such as buildings, monuments, landscapes, paintings, etc. Intangible attributes refer to languages, traditions or rules of behavior of a specific country. If we have a look at recent virtual heritage projects and related games, we can see that they mainly deal with physical (or tangible) artifacts, but often overlook the intangible aspects of cultural heritage. It is one goal of this thesis to fill this gap and investigate the possibilities of virtual worlds in the field of intangible cultural heritage attributes.

1.1 Research Questions

This thesis is grounded on three research questions that derive from the discussed motivations and the problem statement. These questions will be referred to at the relevant Sections. Chapter 8 gives a detailed discussion and critical reflection of the results.

The first research question deals with the principal ability of games to transfer knowledge and raise interest in the cultural heritage domain. This issue was encountered by the design, implementation and evaluation of two serious heritage games. The first one, *ICURA*, is targeted at intangible artifacts of cultural heritage and deals with understanding of contemporary culture, language, rules of behavior and etiquette of a specific country. The second one is called *ThIATRO* and communicates concepts of art history and raises the interest in museums and cultural heritage in general. In addition to quantitative evaluations to check the learning outcomes of both games, qualitative questionnaires were used to check the interests in a specific matter before and after playing the games. The interpretation of the results give a first insight in the success of the artifacts that were created in the course of this PhD thesis.

Research Question 1: Do serious heritage games transfer knowledge about tangible and intangible attributes of cultural heritage?

Research question two investigates ways of knowledge presentation in serious heritage games. An extensive literature study provides the basic knowledge to understand how games integrate teaching materials in general. A review of prior and recent digital game-based learning applications helped to establish understanding for learning mechanisms in games and why some learning games fail to communicate knowledge to their players. This knowledge was then trans-

ferred to the cultural heritage domain to see, which means work best to design games with an optimized learning success.

Research Question 2: Which means do serious heritage games provide to integrate and communicate knowledge? How do these means affect the efficiency of knowledge communication?

Finally, research question three raises the issue of the effectivity of serious heritage games in comparison to prevalent teaching methods. As discussed in the previous Section, education in school and corporate training is often perceived as non motivating to the games generation and provides hardly any intrinsic motivational factors. This thesis investigates novel ways of teaching in the cultural heritage domain. The demonstrated approach follows a constructivist learning method that grasps the attention of the player to generate motivating and vivid learning environments. In an evaluation session that was conducted with a school class of 14 years old pupils we compare prevalent teaching methods with our approach to test the overall efficiency.

Research Question 3: Are serious heritage games more effective to teach cultural heritage issues than traditional training or classroom teaching?

1.2 Scientific Framework

This thesis was carried out between February 2009 and April 2012. The work was conducted in the scientific framework of two projects, both funded by the Austrian Science Fund (FWF). The first one is called "**Itchy Feet - A 3D e-Tourism Environment**" (project reference number L363). The project started in May 2007 and was completed in May 2010. The principle goal of the project was the creation of a novel 3D e-Tourism environment to research the potential of 3D Virtual Worlds in the context of e-Tourism. This principal goal subsumed the following three subgoals [Berger et al., 2007] (see also [Berger et al., 2006]):

- Provide a 3D e-Tourism environment for providers and consumers that enables versatile interaction between participants including the trade in tourism products.
- Provide a 3D e-Tourism environment that becomes a community facilitator to create and establish a lively and sustainable community involving both, providers and consumers.
- Provide a 3D e-Tourism environment that is information-rich and multimedia-based to offer transparent and unified access to disparate information sources.

Basically, Itchy Feet provides the tools to browse and book hotels and flights, take part in virtual auctions and chat with other avatars about tourism related topics. All the interaction takes place in a game-like 3D virtual environment. The first task in the beginning of 2009 was to create the 3D models for this vivid virtual world of Itchy Feet. In order to ensure the functionality for e-tourism related tasks, three virtual buildings had to be modelized. The *Travel Agency building* contains the functionality that enable the search for fixed price products, such as flights and hotel, and offers booking and payment services. In the *Auction House building* auctions are conducted

Figure 1.1: The 3D world of "Itchy Feet" - upper left: Travel Agency, upper right: Auction Building, lower left: Forum Building, lower right: the "Karlskirche".

by agents and payment services are provided. The *Forum Building* includes agents that provides access to an external Web forum. In addition, the baroque church "Karlskirche" was recreated to show the users a typical Viennese sight. The whole functionality and the underlying agent system is described in detail in Ingo Seidel's PhD thesis [Seidel, 2010]. Figure 1.1 shows four screenshots of the 3D models and their integration into Itchy Feet.

The design of the 3D world for Itchy Feet provided an instructive starting point to get familiar with modern game engines and light-weight 3D modeling tools. In this specific case *Torque 3D Game Engine*[1] and the *Torque Constructor*[2] were used to implement the functionality and to create the 3D objects. The abilities gained in this early stage of the doctorate provided a vital basis for coming challenges. After achieving the project's main goals, further steps were considered to enrich the virtual e-tourism environment with supplementary content. The project's team came up with the idea to integrate a serious gaming application into Itchy Feet that can be accessed by the users to get additional information on possible travel destinations. The game, which was later called ICURA, teaches some language basics, habits and rules of behavior of the Japanese culture. We chose Japan as subject matter because it's cultural uniqueness provides a rich source of interesting teaching content. Basically, ICURA teaches intangible artifacts of

[1] http://www.garagegames.com/ - last accessed: Jan 31, 2012
[2] http://www.garagegames.com/products/constructor - last accessed: Jan 31, 2012

cultural heritage. A detailed description of the design and evaluation of the game, can be found in Chapter 6.

In April 2010 work on the Itchy Feet project was finished and we continued research within the context of the second project, "**VŠEM - The Virtual 3D Social Experience Museum**" (project reference number L602). The project officially started in April 2009. The principal goal of this project is to connect the diversified fields of art history and computer science by novel means of technology. VŠEM aims at communicating art history to a wide audience of experts and lay persons at the same time. In succession, the developed tools shall help to support the bidirectional interaction between museums and their visitors. The principal goal subsumes three sub-goals:

- Provide a platform for 3D museum installations in a multi-user virtual environment
- Provide a platform for user-generated textual and multimedial annotations to artefacts
- Analyze user interaction patterns with the virtual museum installation.

The project team comprises four members: Dieter Merkl, the scientific supervisor, and three PhD students - Max Arends and Doron Goldfarb, who where involved in the project from the beginning, any myself. In the initial phase current best practices for museum-visitor interaction on the Web were surveyed and published in the book chapter "Museums on the Web: Interaction with Visitors" [Arends et al., 2011c]. Later on in the project each of us PhD students turned towards an own thematic focus. The work of Max Arends concentrated on the creation of the webtool explorARTorium[3] that visualizes artworks in context and allows users to browse along different narratives. By providing the possibility to annotate or tag artworks, a folksonomy is created that is then analyzed via data mining algorithms to show the possibility of reproducing certain art historical facts [Arends et al., 2011a]. Doron Goldfarb designed a prototype that automatically constructs a 3D environment from semantic art history related Web resources, offering users the opportunity to explore art history following the visualized structure of relations between historical actors of the field. Traversing this historical social network enables users to encounter previously unknown artists and their work in a serendipitous way [Goldfarb et al., 2011a]. For myself, this project provided the framework for the second artifact that is presented in this thesis. ThIATRO is an online serious heritage game, which helps students learn art history. By recreating 3D virtual museums, the game immerses the player into an exhibition and thus raise the curiosity to engage with art and to create a persistent idea of art historical concepts. The work provides tools for classroom use and general tools for everyone who wants to gain knowledge in the area of art history. After completion of our prototype, ThIATRO was evaluated in April 2011 at an Austrian middle school. A detailed description of the design process and the evaluation results can be found in Chapter 7.

[3] www.explorARTorium.info - last accessed: Feb 08, 2012

1.3 Thesis Outline and Publication Record

The results of the work and the contribution to the research community described in this thesis have been published in several peer-reviewed conference proceedings. This Section outlines the overall structure of the work, sums up the content of each relevant publication and where it can be found within the PhD thesis.

The remainder of the thesis is structured as follows. In Chapter 2 the research methodology is described in detail. We follow the *Design Science Research* approach by Hevner et al. [Hevner et al., 2004] that contains good guidance on how to conduct, evaluate and present a scientific project. We outline the proposed builds and evaluation methods, specify the research contributions and describe the design science research guidelines.

Chapter 3 introduces the thematic field and discusses recent aspects of computer games culture. We investigate the ways digital natives deal with computer games and compare these insights with the habits of digital immigrants. Starting from this conflict of generations, we have a look at cognitive style changes of the younger generation and how science and education can benefit from these rapid developments. To understand how modern games work, we define the terms *fun*, *play* and *games*. After a short introduction into the field of game design, we introduce the term *serious gaming*.

In Chapter 4 we go into more detail and concentrate on the field of games for education and digital game-based learning. Beginning with a brief history of digital learning applications, the current situation of learning in schools and corporate training is analyzed and possible drawbacks and suggestion for improvement are presented. The following Section shows new ways of learning and presents common theories of how digital game-based learning is working and why games are considered as powerful mediators of knowledge.

Chapter 5 addresses the area of games that exclusively deal with cultural heritage. We outline the most recent research results and present an extensive collection of related work. We discuss how the work of this thesis fits into the related work, where it differs and where we see a gap in research to contribute new knowledge. We start with a collection of serious games examples, followed by prototypes, demonstrators, virtual museums and commercial historical games.

Chapter 6 introduces the practical part of this PhD thesis. We describe the planning phase, design, implementation and evaluation of the first artifact, named ICURA. We outline its thematic importance, how we integrated given design principles for learning games and give a summary of experiences we made during the design process. The results of the evaluation are presented in detail, followed by a discussion. The entire work has been published as a full paper and has been presented at the International Conference on Virtual Systems and Multimedia (VSMM) in 2010.

> [Froschauer et al., 2010] Josef Froschauer, Ingo Seidel, Markus Gärtner, Helmut Berger, and Dieter Merkl. Design and Evaluation of a Serious Game for Immersive Cultural Training. In *International Conference on Virtual Systems and Multimedia (VSMM)*, pages 253-260, Seoul, Korea, 2010. IEEE Computer Society.

Chapter 7 continues with the second artifact of this thesis, the serious heritage game ThIATRO. Again, we describe the planning phase, design, implementation and evaluation in detail. In addition, we focus our attention on art history in games and how we can change the player's perception of art by means of technology. A proposal that outlines the idea of ThIATRO was published and presented at the VS-GAMES Conference in 2011.

> [Froschauer et al., 2011a] Josef Froschauer, Max Arends, Doron Goldfarb, and Dieter Merkl. Towards an Online Multiplayer Serious Game Providing a Joyful Experience in Learning Art History. In *International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES)*, pages 160-163, Athens, Greece, 2011. IEEE Computer Society.

The final version, including an in-depth description of the game and details about the evaluation was accepted for publication at the International Conference on Virtual Systems and Multimedia (VSMM) 2012.

> [Froschauer et al., 2012a] Josef Froschauer, Max Arends, Doron Goldfarb, and Dieter Merkl. A Serious Heritage Game for Art History: Design and Evaluation of ThIATRO. In *International Conference on Virtual Systems and Multimedia (VSMM)*, 2012. IEEE Computer Society. Accepted for publication.

Continuing with Chapter 8, we compare the design process of both games, ICURA and ThIATRO, and examine differences, obstacles and the lessons we have learned by designing serious heritage games. According to our experiences, we define and discuss different design guidelines. Again, our research questions are referenced and detailed answered are given. We conclude the Chapter with a discussion of open issues. The following publication describes both games and summarizes the lessons we have learned that may also help other developers to design successful learning games.

> [Froschauer et al., 2011b] Josef Froschauer, Max Arends, Doron Goldfarb, Martin Weingartner, and Dieter Merkl. Designing Socio-Cultural Learning Games: Challenges and Lessons Learned. In *International Conference on Information Society (i-Society)*, pages 56-61, London, UK, 2011. IEEE Computer Society.

The last paper of the VŠEM project (and a possible direction to future work) covered the prototypically implemented mobile-phone based Android game *ARTournament* and is based on the master thesis of Johannes Zweng [Zweng, 2011]. ARTournament provides the framework for a dynamic content creation (or authoring) tool that lets the tutor (or teacher) compose own learning scenarios.

> [Froschauer et al., 2012b] Josef Froschauer, Johannes Zweng, Dieter Merkl, Max Arends, and Doron Goldfarb. ARTournament: A Mobile Casual Game to Explore Art History. In *International Conference on Advanced Learning Technologies and Technology-enhanced Learning*, accepted for publication, Rome, Italy, 2012. IEEE Computer Society.

Finally, Chapter 9 concludes the thesis. The results are summarized and possible directions for future work and future research are given.

The initial step for the first publication in the field of knowledge communication in virtual worlds was already taken in 2008. The project "Research Exhibition & Experience Landscape (REEL)" was supported by grants of the Austrian Science Fund (FWF) and aimed at investigating the possibilities of the multi-user virtual environment Second Life[4] in the field of science communication. The resultant paper was published in 2009 and presented in Vancouver, BC at the E-LEARN Conference. The paper present the virtual learning environment *REEL*, a platform for communicating scientific projects. REEL allows users to observe and actively participate in scientific research. Hands-on experiences in the virtual world of Second Life allow the student to directly step in the field of research and learn in a playful way. REEL showcases the results of the e-Tourism project "Itchy Feet" that was described in the previous Section. Note that the content of this publication is not part of the PhD thesis.

> [Froschauer et al., 2009] Josef Froschauer, Ingo Seidel, Markus Gärtner, Helmut Berger, and Dieter Merkl. New directions in science communication: A Virtual Research & Experience Landscape. In *Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare & Higher Education (ELEARN 2009)*, pages 26-30, Vancouver, BC Canada, 2009. AACE.

Within the three years of writing, additional papers have been published within the two research projects Itchy Feet and VŠEM. For the sake of completeness, the following list references the publications that I was actively contributing to, but not as first author.

> [Seidel et al., 2009] Ingo Seidel, Markus Gärtner, Josef Froschauer, Helmut Berger, and Dieter Merkl. An Agent-Based Centralized e-Marketplace in a Virtual Environment. In Proceedings of the International Conference on Software Engineering and Knowledge Engineering (SEKE 2009), Boston, MA, July 1-3 2009.

> [Seidel et al., 2010] Ingo Seidel, Markus Gärtner, Josef Froschauer, Helmut Berger, and Dieter Merkl. Towards a Holistic Methodology for Engineering 3D Virtual World Applications. In *Proceedings of the International Conference on Information Society*, London, UK, 2010. IEEE Computer Society.

> [Gärtner et al., 2010] Markus Gärtner, Ingo Seidel, Josef Froschauer, and Helmut Berger. The formation of virtual organizations by means of Electronic Institutions in a 3D e-Tourism environment. *Information Sciences*, 180, pages 3157-3169, 2010.

> [Gärtner et al., 2011] Markus Gärtner, Ingo Seidel, Josef Froschauer Helmut Berger, and Andreas Rauber. Ontology-based Web Mining and Hybrid Semantic Search in the Tourism Domain. *Ontologies Driven Web Mining: Concepts and Techniques.* Accepted for publication.

[4] www.secondlife.com - last accessed: Feb 9, 2012

[Arends et al., 2010] Max Arends, Josef Froschauer, Doron Goldfarb, Dieter Merkl, and Martin Weingartner. Interaktion mit musealen Inhalten in Web3D. In *EVA 2010 Berlin - Elektronische Medien & Kunst, Kultur, Historie*, pages 161-167, 2010.

[Goldfarb et al., 2011b] Doron Goldfarb, Max Arends, Josef Froschauer, Dieter Merkl and Martin Weingartner. Combining Cultural Heritage Related Web Resources in 3D Information Landscapes. In *EVA London - Electronic Visualisation and the Arts*, London, UK, pages 73-80, 2011.

[Goldfarb et al., 2011a] Doron Goldfarb, Max Arends, Josef Froschauer and Dieter Merkl. Revisiting 3D Information Landscapes for the Display of Art Historical Web Content. In *Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology (ACE '11)*. Lisbon, Portugal, 2011. ACM Press.

[Arends et al., 2011a] Max Arends, Josef Froschauer, Doron Goldfarb and Dieter Merkl. Analysing User Generated Content Related to Art History. *In Proceedings of the 11th International Conference on Knowledge Management and Knowledge Technologies (i-KNOW '11)*, pages 12:1-12:8, Graz, Austria, 2011. ACM Press.

[Arends et al., 2011b] Max Arends, Josef Froschauer, Doron Goldfarb, Dieter Merkl, and Martin Weingartner. Vermittlung kunstgeschichtlicher Inhalte durch die Kontextualisierung von Kunstwerken. In *EVA 2011 Berlin: Elektronische Medien & Kunst, Kultur, Historie*. 2011.

[Weingartner et al., 2011] Martin Weingartner, Max Arends, Josef Froschauer, Doron Goldfarb, and Dieter Merkl. Analyse der Tags einer Kunst Folksonomy. In *EVA 2011 Berlin: Elektronische Medien & Kunst, Kultur, Historie*. 2011.

CHAPTER 2

Methodology

2.1 Design Science Research

This thesis follows the design science paradigm as outlined by [Hevner et al., 2004]. In the design-science paradigm, knowledge and understanding of a problem domain and its solution are achieved in the building and application of the designed artifact [Hevner et al., 2004]. Within this framework we seek to develop new ideas by means of creating prototypical artifacts and to conduct evaluations of theses artifacts. A graphical illustration of Hevner's approach is presented in Figure 2.1. The knowledge base on the right side provides the raw materials from and through which our research is accomplished. The environment at the left side defines the problem space in which reside the phenomena of interest. For research, it is composed of people, organizations, and their existing or planned technologies. The research activities, containing the final artifacts, theories and evaluation results, are depicted in the middle.

Furthermore, as part of Information Systems Research Framework, the authors categorize scientific work with the *Knowledge Contribution Framework*, as depicted in figure 2.2. Dependent on the two factors, Application Domain Maturity and Solution Maturity, Hevner et al. define four types of research:

- *Routine design* is to apply known solutions to known problems and does not contribute to the knowledge base. Routine design does not provide research opportunity.
- *Inspirational research* develops new solutions to known problems.
- *Exaptation* extends known solutions to new problems.
- *Inventional research* invents new solutions for new problems.

It is a known issue that that education is largely non motivating to the games generation and that cultural heritage preservation is developing in a changing world and professionals have to adapt to these changes. To raise the interest in younger generations in this topic we make use

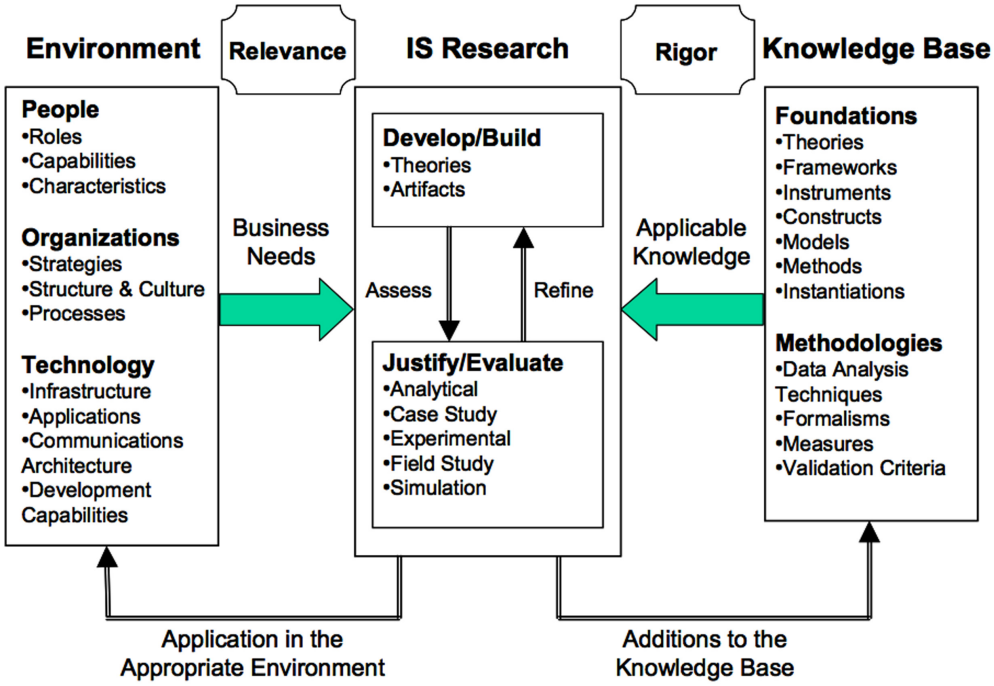


Figure 2.1: Information Systems Research Framework [Hevner et al., 2004]

of novel techniques, such as serious gaming and digital game-based learning. According to the Knowledge Contribution Framework, we can classify the research as inspirational (providing new solutions to known problems). Serious heritage games are a quite new area of research. Thus, the problem that intangible artifacts are often overlooked by serious heritage applications, is a new one. So we can place parts of this project into the quadrant of *Invention*.

Hevner et al. propose four different entry points for research: *Problem Centered Initiation*, *Objective Centered Solution*, *Design and Development Centered Approach* and *Observing A Solution*. [Hevner et al., 2004]. In terms of a Problem Centered Initiation we have started by identifying and defining a specific problem and showing its importance. Next we were thinking about appropriate artifacts to face this problem, followed by a design and development phase. In the course of a rigorous evaluation these artifacts were tested against efficiency and effectiveness. In a final step, results were communicated on project websites and various publications. Figure 2.3 visualize the iterative process model and our entry point.

2.2 Proposed Builds and Evaluation Methods

Within the scope of this thesis, two serious heritage games were planned, implemented, analyzed and evaluated. The first one, ICURA, is targeted at understanding contemporary culture, learning about language, rules of behavior and etiquette of a specific country. The game was designed along the lines of an adventure game and deals with intangible attributes of cultural heritage.

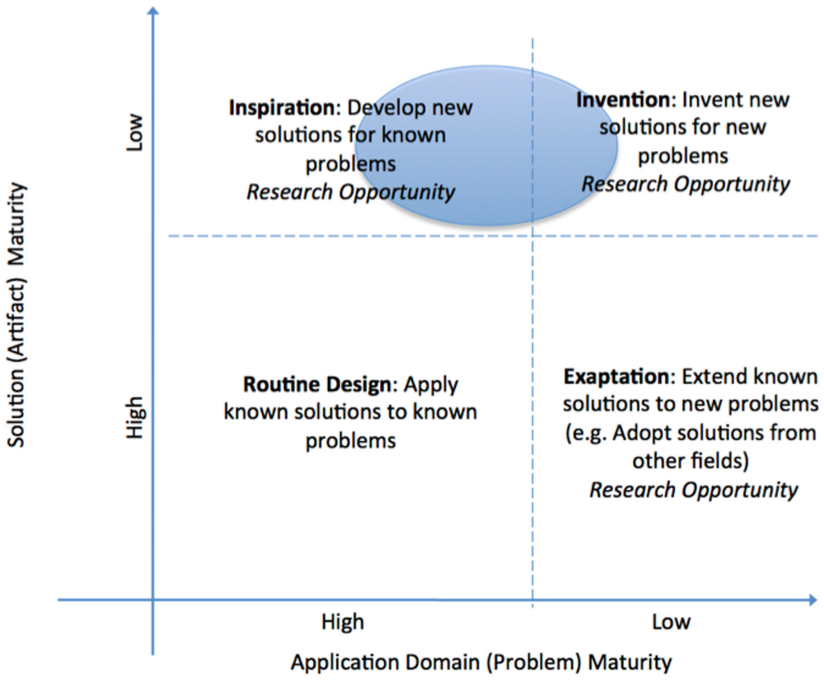


Figure 2.2: DSR Knowledge Contribution Framework

The second one, ThIATRO, teaches concepts of art history and raises the interest in museums and cultural heritage in general. This game deals with tangible (or physical artifacts). The game resembles a virtual scavenger hunt game that lets the player slip into the role of a museum curator.

A common approach to analyze the effectiveness of serious games is the comparison of pre- and post-test results to highlight the learning effect. In addition, questionnaires are used to collect demographic data and to detect strengths and weaknesses in game design and usability. A more extensive approach splits up the test group into an experimental group that plays the game, and a control group that is taught using prevalent methods such as classroom teaching. Both approaches can be expanded by re-checking the knowledge gain after some time to get an insight if the information was stored permanently. The pre-test/post-test approach was used to evaluate our first artifact ICURA. It allowed us to check, if the game compels the player to think about, organize and use information in ways that encourage active construction of knowledge. In addition, a qualitative questionnaire shows, if there are significant changes in the user's perception and cultural awareness towards a country or society. The second artifact ThIATRO was evaluated using the control group/experimental group approach. The main goal of this game is to raise the interest in art history of a younger generation. So it seemed reasonable to conduct this part of the evaluation with a school class with support of an arts teacher. After checking the previous knowledge of each pupil, the school class was split up into two groups. The experimental group played the game and the control group was taught in class by their teacher. Afterwards

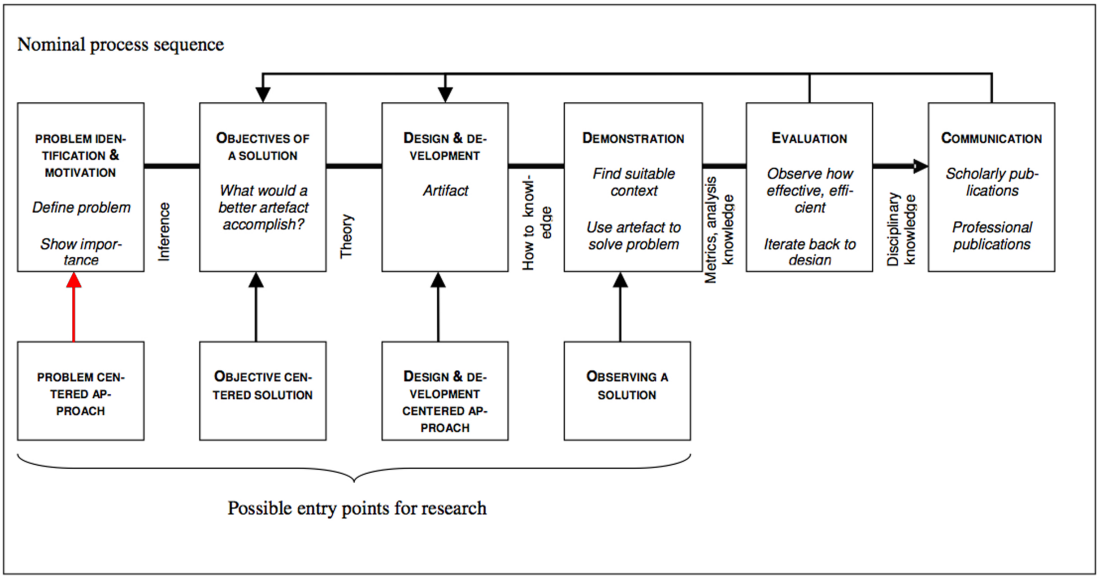


Figure 2.3: DSR Process Model. The red arrow indicates our entry point. Adapted from [Hevner et al., 2004]

the learning results were compared to get an insight in the success of both approaches.

2.3 Research Contributions

The proposed project makes clear and useful contributions to the application environment and the knowledge base. For the application environment we aim at:

- providing teaching tools for everyone, who is dealing with preservation of cultural heritage.
- providing tools for teachers to use in classrooms.
- providing a chance to learn for everybody, who is interested in the domain.

Concerning the knowledge base, we want to define guidelines and models for the design and evaluation of serious games in the cultural heritage domain. Design guidelines for games that mainly aim at entertainment are well defined and provided a helpful basis for the implementation of the two artifacts. However, there is no research about how to apply theses guidelines for serious gaming applications, especially in the domain of cultural heritage. Our research aims at closing this gap and to provide an adaptive set of principles to design successful games that meet the learner's expectations.

2.4 DSR Guidelines

An important part of Hevner's work concentrates on developing a set of guidelines to assist researchers and readers for conducting good design science research. These seven guidelines are explained briefly in this Section, accompanied by an explanation, how the thesis is organized according to these guidelines.

Design as an Artifact

The Design as an artifact guideline stresses the fact that in design-science research the problem is addressed through the creation of an artifact. Within the scope of this project, two artifacts/serious games have be planned, implemented, analyzed and evaluated. We have already explained the idea behind both artifacts in Section 2.2. The artifacts are both generalizable and specific - generalizable in the sense that the principal technical framework can be reused and applied to other domains - specific in the sense that we implemented a specific 3D environment in the cultural heritage domain.

Problem Relevance

The problem relevance captures the requirement to study problems that are unsolved, relevant to the business environment and provide opportunities that have not been studied yet. The problem, as described in the introduction of this thesis, is interesting and real. It is therefore necessary to create prototypes, apply them within a real-world context and evaluate them against usability and usefulness.

Design Evaluation

The design evaluation guideline describes the artifact's need to be evaluated with respect to the requirements of the environment in order to demonstrate its quality and utility. As mentioned in Section 2.2, comparisons of pre- and post-test results and the control group/experimental group approaches have proven to be effective. Within the scope of this project, both types of evaluations have been conducted within a real-world context in order to provide useful results. The evaluations were designed according to methodologies and approaches of the knowledge base in order to achieve research rigor. They took place in controlled conditions in order to provide valid results and the analysis was performed rigorously in order to answer the research questions.

Research Contribution

The research contributions capture the contributions that are generated as part of the research and described in Section 2.3. The research contributions of this thesis are twofold: The first contribution is the creation of the artifacts itself which provide tools for learners and teachers to use at home or in classroom. Furthermore, both games provide a testbed for conducting research in the field of serious heritage games. Researchers are able to build upon the artifacts, extend them

with additional functionality and apply them in other domains. The second contribution concerns the knowledge base. We define clear guidelines and models for the design and evaluation of serious games in the cultural heritage domain to assist game designers in their work.

Research Rigor

The research rigor is related to the rigorous application of methods and foundations of the knowledge base during the creation and evaluation of the artifact. The rigor is achieved by building on the theoretical foundations of game design theories and digital game-based learning research, as exemplified proposed by Mark Prensky [Prensky, 2003], Katie Salen and Eric Zimmermann [Salen and Zimmerman, 2003], Raph Koster [Koster, 2004] or Ian Bogost [Bogost, 2007]. This project required an extensive study of literature in these fields to guarantee research rigor. We followed rigorous methods in both the construction and evaluation of the artifacts to provide the basis for successful serious games design that fulfills the learner's needs.

Design as a Search Process

Design as a search process describes how the solution to the problem is generated. An iterative and heuristic search strategy is proposed as a good and feasible strategy to develop an artifact that is applicable to the environment. An extensive literature study at the beginning of the thesis clearly showed that computer games are becoming more and more popular among teenagers and adults. The initial search process made it self-evident to use the method of gaming to communicate knowledge in an entertaining way. At the same time we observed that powerful game engines are no longer high priced software packages. Instead many independent studios start providing effective solutions to the public for a very fair price (such as *Torque3D* and *Unity3D*). As a next step, research was conducted as a search process where we acquired knowledge on the application domain of game design, learning theories, serious gaming and digital game-based learning.

Communication of Research

The outcome of the research has been presented from a technical point of view as well as from an application point of view. See Section 1.3 for a complete list of publications. Additionally, the project's progresses were documented on two websites, `http://www.itchy-feet.org` and `http://vsem.ec.tuwien.ac.at/`. One essential part of the communication included the upload of current builds of both artifacts. We motivated the community to provide us with useful feedback to draw conclusions from our work.

CHAPTER 3

Computer Games Culture

"We don't stop playing because we grow old,
we grow old because we stop playing."
(George Bernard Shaw, 1856-1950)

Computer games are a very young phenomenon and struggle for acceptance as a form of culture. They are still perceived as a child medium "easily denigrated as trivial - something that will be 'grown out of"' [Bogost, 2007]. In contrast to well-established media, such as literature and film, video games are considered as "low art, carrying none of the weight, gravitas or credibility of traditional media" [Bogost, 2007]. On the other side, there is the much discussed possibility that games could succeed film as the defining form of popular culture for the new century. According to Salen and Zimmerman, games have their own unique aesthetic, the aesthetic of interactive systems [Salen and Zimmerman, 2003]. This characteristic makes them so exciting for a younger generation that is eager to be actively engaged in their lives rather than being branded as passive observers.

In this Chapter we will compare the differences of today's gamers generation to a generation that grew up without digital media. Based on this resulting conflict we will sum up the cognitive style changes of today's youth, as they were identified by American scientist Marc Prensky. To understand how games are actually able to grab our attention for hours, we continue with defining the terms *fun*, *play* and *games*, followed by a brief introduction into the field of game design. Although this thesis is not intended to be an extensive essay on game design, it is still important to understand some core concepts, as defined by renowned researchers like Eric Zimmerman, Mark Prensky or Ian Bogost. This knowledge will be important for latter parts of the thesis, especially when we deal with the design of the two artifacts ICURA and ThIATRO. We will conclude the Chapter with an introduction into the field of serious gaming.

3.1 A Conflict of Generations

As already mentioned in the introduction of this thesis, Mark Prensky coined the term *digital natives*, referring to a generation that sees digital media (and thus games) as an essential part of their daily lives. Anyone born in the United States after 1961 almost certainly grew up with digital games in their life, either at home at the mall or movie theatre [Prensky, 2001a]. Those who were born earlier (referred to as *digital immigrants*) may not see new media as granted and sometimes have prejudice against a younger generation. An often cited misbelief is that the attention spans of digital natives are shorter. Some even say, "they have the attention of a gnat" [Prensky, 2001a]. In his 2001 paper Mark Prensky poses the question if digital natives really think differently in comparison to their ancestors [Prensky, 2001c]. He suggests that their brains are likely physically different as a result of digital input they received growing up. They have been adjusting or programming their brains to the speed, interactivity and other factors in the games, much as the older generation's brains were programmed to accommodate TV [Prensky, 2001a]. Prensky's evidence for his assumption comes from the fields of neurobiology and social psychology. According to the work of Renate and Geoffrey Caine, the human brain is no static organ, in fact it can be, and is, constantly reorganized [Caine and Caine, 1991].

> *"The brain constantly reorganizes itself all our children and adults lives, a phenomenon technically known as* neuroplasticity*."* [Prensky, 2001c]

Children raised with computers (and digital games) develop different ways of thinking than digital immigrants do. Prensky further says that young people's facility with computers can be seen as a second language, one that the elders do not speak, or at least with an accent. These cognitive style changes cause a conflict of generations that also comes to light in our educational system. Today's teachers are dealing with a generation that thinks (and learns) in completely different ways as they do. The learners have changed from being passive observers to active participants. Children are often accused of not paying attention in school, but accordingly to Prensky, they just choose not to [Prensky, 2001a]. By sticking to old ways of learning, we offer this generation very little not paying attention to from their perspective. This seems obvious when we think of the high degree of interactivity and excitement that modern games offer to their players. We are facing the problem that teachers and pupils are from totally separate worlds, heavily influenced by the impact of video games. As a consequence, scientists and pedagogues around the world eagerly try to integrate digital games into the classroom. What might sound simple is actually a real challenge and a highly controversial topic. In general, there are two groups of teachers: on the one side, there are those, who are excited when they see the potential of digital games, and on the other side are those, who say "we don't want to fall prey to the 'education has to be fun' mentality" [Prensky, 2001a]. Michael and Chen say that teachers fear negative reactions from other teachers and parents, a lack of examples of how games can be integrated in the curriculum, a lack of validation of games as teaching tools and worry that school computer are insufficient to run modern games [Michael and Chen, 2005]. James Paul Gee cites a teacher who said the following: "While it may be good for his (the pupil's) hand-eye coordination, it's a waste of time, because there isn't any content he's learning" [Gee, 2004]. Clark C. Abt already referred to the teacher's fears in 1970 by saying that "games (meaning card-

and board games for educational purpose) would keep teachers too busy to do their jobs" [Abt, 1970]. Forty years later, these fears are still evident and games struggle for acceptance more than ever. American game designer Raph Koster expresses the sum of all fears is one timeless quotation:

> *"Painting was once a blasphemous act that robbed reality of its essence. Dance was seen as wantonness incapable of expressing any higher emotions. The novel was self-indulgent gothic nonsense for cooped-up housewives. Film was once trashy kinetoscopes at the penny arcade, unworthy adult attention. Jazz was devil music, Rock 'n' roll was destroying the fabric of our country. We learned better."* [Koster, 2004]

3.2 Cognitive Style Changes

As mentioned in the previous Section, today's younger generation experiences cognitive style changes to adapt to greater speed and interactivity. Since childhood, they have been exposed to TV shows and digital games that combine text, graphics and sound in a rich and meaningful way. In his book "Digital Game-Based Learning", Mark Prensky lists ten cognitive style changes that he observed in the games generation [Prensky, 2001a].

- Twitch speed vs. conventional speed: The games generation has had far more experience at processing information quickly than its predecessors and is therefore better at it.
- Parallel processing vs. linear processing: Their minds can actually process many tracks at once and feel much more comfortable than their predecessors when doing more than one thing at the same time.
- Graphics first vs. text first: They find it much more natural to begin with visuals and to mix text and graphics in a rich and meaningful way.
- Random access vs. step-by-step: Hypertext has freed them form the constraints of a single path of thought. They can decide where to enter the learning content.
- Connected vs. standalone: The games generation is connected both synchronous (e.g. multiplayer games or instant messaging) and asynchronous (e.g. email or bulletin boards) - anytime, anywhere, at almost no cost.
- Active vs. passive: Mark Prensky describes the games generation workers as people, who rarely even think of reading a manual.
- Play vs. work: For today's games generation play is work, and work is increasingly seen in terms of games and gameplay.
- Payoff vs. patience: If you put in the hours and master the game you will be rewarded, and the payoff for any action is typically extremely clear. So is it worth to put in the effort? Games generation people make these payoff-versus-patience decisions every minute.

- Fantasy vs. reality: Fantasy elements, both from the past and the future, pervade the lives of the games generation. This also gets apparent in the design of their workspaces, that are very different from those of their predecessors.
- Technology-as-a-friend vs. technology-as-a-foe: As already mentioned in the introduction, to much of the older generation, technology is something to be feared, tolerated. To the games generation, the computer is a friend.

3.3 Fun, Play and Games

In order to understand how games work as powerful and motivating learning machines, it is important to investigate their impact on human brains and how they achieve to tie us to our computers for hours. Before defining the term *game*, we will concentrate on the underlying concepts of *fun* and *play*, which provide the basis for an exciting gaming and learning experience.

A good game is fun to play. This simple phrase combines three central terms in game design that are closely connected to each other. But where can we draw the border between informal play without rules and an organized game? How is it that play begins and ends? The German language does not even distinguish between the two words: "ein Spiel spielen" means to "play a game". We will start with the underlying concept of fun that is so important for good games and a great motivator for learning.

Fun, as Raph Koster defines it, is the feedback the brain gives us when we are absorbing patterns for learning purposes [Koster, 2004]. So every time a game teaches us some new information (e.g. a new tactic to conquer our enemies or an effective way to cast our spells) and we succeed to put this newly gained knowledge into action, our brain rewards us with a feeling of enjoyment. And fun is defined as the source of enjoyment. In other words, with games, "learning is the drug" [Koster, 2004]. As soon as a game stops teaching us, we feel bored. The pencil-and-paper game TicTacToe is a good example for a badly designed game. Usually the players figure out how the game works from just the first five minutes. Once the player has mastered it, or realized she can't get any better, she dismisses it as trivial. The game is too easy. As an exact opposite, chess provides to the players a great variety of combinations and strategies to conquer opponents. Even professionals never complete training. In the long run, no one will deny that chess is more fun than TicTacToe. So fun in the sense of enjoyment and pleasure puts us in a relaxed, receptive frame of mind for learning [Prensky, 2001a]. Play increases our involvement, which also helps to learn. in his 1950s book "Homo Ludens", Dutch philosopher and historian Johan Huizinga characterizes play as a free activity that is consciously outside of "ordinary life" and is "not serious". Play, he says, absorbs the player "intensely and utterly" [Huizinga, 1938]. Furthermore, he describes six characteristics of play:

- Voluntary: play is a form of freedom
- Pretend: play is not "real life"
- Immersive: it takes up the player's full attention

- Limits: Play happen within certain limits of time and space
- Rules: Play is based on rules and no profit can be gained from playing
- Social: Play is social, creating a social group of players

In this early characterization Huizinga does not differentiate between the terms play and game. These six characteristics also describe most games, regardless of whether card-, board-games or digital games. According to Salen and Zimmerman, most forms of play are less organized than games [Salen and Zimmerman, 2003]. Consider a child practicing some ball tricks. No one would claim that she is playing a game, she is just "playing around". But as soon as her teammates enter the field and everyone takes her position, the game starts. Everyone on the field accepts the rules and limits of time and space and enters a game state. Salen and Zimmerman call this phenomenon "the magic circle" [Salen and Zimmerman, 2003]. As a player steps in and out of a game he or she is crossing that boundary - or frame - that defines the game in time and space. Figure 3.1 provides a diagram of the relations between play and games.

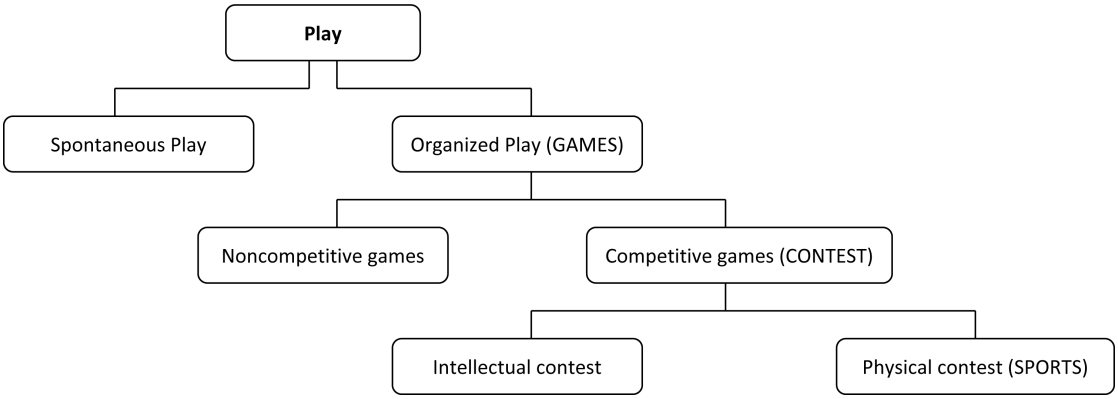


Figure 3.1: Diagram of the relations between *play* and *games*. Adapted from the Encyclopedia Britannica: `http://www.britannica.com/` - last visited: Feb 17, 2012

Over the course of time there have been many definitions of the term "game". The following Section gives an overview of the most important ones and how the authors comment on them. As already mentioned, Johan Huizinga defined the term play in the 1950s and does not differentiate between play and games. He also mentioned that a game absorbs the player "intensely and utterly". The problem with this definition, according to Salen and Zimmermann, is that just because a game fails to be absorbing, does not mean that it is not a game [Salen and Zimmerman, 2003] (see TicTacToe as an example). In his 1970s book "Serious Games" Clark C. Abt defines games as follows [Abt, 1970]:

> *"Reduced to its formal essence, a game is an activity among two or more independent decision makers seeking to achieve their objectives in some limiting context. A*

more conventional definition would say that a game is a context with rules among adversaries trying to win objectives."

Abt himself adds that not all games are contests among adversaries and in some game the players cooperate to achieve a common goal [Salen and Zimmerman, 2003]. Game historian David Parlett, mostly writing about card- and board-games, begins his definition of games by distinguishing between formal and informal games. Informal is "playing around" (like the kid with the soccer ball). A formal game has "ends" (e.g. a win-state) and "means" (or rules) to produce the winning state [Parlett, 1999]. Parlett introduces the terms ends and means, or rules, into his definition that we will find in later definitions as well.

The next significant definition was given by play theorist Brian Sutton-Smith in this 1971 book "The Study of Games" [Avedon and Sutton-Smith, 1971]:

"Games are an exercise of voluntary control systems, in which there is a contest between powers, confined by rules in order to produce a disequilibrial outcome."

Sutton-Smith says that games are played voluntarily and are controlled by a system of given rules. What is new in his definition is the term *disequilibrial*, meaning that the outcome of a game is a goal state, which differs from the starting state.

Finally, the most recent definition is by Salen and Zimmermann in their book "Rules of Play" [Salen and Zimmerman, 2003]:

"A game is a system in which players engage in an artificial conflict, defined by rules that result in a quantifiable outcome."

The authors list the definition's primary ideas:

- System: A game is one kind of system embedded in a surrounding environment.
- Players: A game is played actively by one or more players. Players interact with the system.
- Artificial: Games maintain a boundary from so-called "real-life".
- Conflict: All games embody a contest of powers, either in the form of cooperation or competition.
- Rules: Rules provide the structure of every game by defining what the player can do and cannot do.
- Quantifiable outcome: Games have a quantifiable goal or outcome. At the end of a game, a player has some kind of numerical score. This is what usually distinguishes games from less formal play activities.

Digital Games

Salen and Zimmerman's definition covers every aspect of games and leaves no more space for uncertainties. And now that we have defined this important term, let us have a look at games in general and the specifics of digital games. In his 1958 book "Man, Play and Games", Roger Caillois divided (pre-computer) games into four classes: competition, chance, simulation and movement [Caillois, 1961]. Later, in 1984, game designer Chris Crawford identified five major types of games: board games, card games, athletic games, children's games and computer games [Crawford, 1984]. He was the first one to classify digital games as an self-contained category. Today's computer games generally fall into one of the following genres: action, adventure, fighting, puzzle, role playing, simulations, sports or strategy. We can clearly see that digital games differ a lot from traditional games. But what exactly is it that makes them so fascinating? According to Mark Prensky, the biggest difference is that computers enhance the "play experience" [Prensky, 2001a]. One thing the computer does well is to take care of the boring little rules and details, freeing the player to enjoy more of the play experience [Prensky, 2001a]. In addition, they allow real-time. For example, Let us consider the game *Command & Conquer* (C&C)[1]. C&C , initially developed by Westwood Studios between 1995 and 2003, is a real-time strategy game that allows countless events to happen at the same time. Despite its high degree of complexity, the game never overstrains the player because it takes care of all the little processes in the background. Otherwise the player might lose control over the game and fails to see any patterns. And nothing is more boring than noise [Koster, 2004]. Another famous example that would be unrealizable in this form as board game is Sid Meyer's *Civilization*[2]. Civilization is a series of turn-based strategy games, initially developed by Microprose in 1991. The basic gameplay functions are similar throughout the series, namely building a civilization from prehistoric age up to the near future. The player founds cities, moves units, initiates negotiations with computer-controlled players and chooses technologies to research. The game arranges all the important steps in the background, invisible to the player, to guarantee a fluid gameplay. It only halts the game when it is supposed to do. Due to the exemplary design of the game, the player never has the feeling of losing control. These two examples show us that digital games are excellent at hiding information from players and revealing it when necessary. Furthermore, they can automate complicated processes and facilitate play of games that would be too complicated. They move the games forward without direct input of the player. According to Salen and Zimmerman, digital games additionally offer immediate and interactive feedback [Salen and Zimmerman, 2003]. The game responds seamlessly to the player's input and the gameplay reacts dynamically to player decisions.

Another characteristic of a digital game is that it teaches the rules as it is being played. Many games make the discovery of the way that the game operates part of the play, mostly in form of a playable tutorial at the beginning of a level. In a board-game, for comparison, it is necessary for at least one of the players to learn the rules. The last thing that Salen and Zimmerman emphasize is the "encyclopedic quality" of games [Salen and Zimmerman, 2003].

[1] See `http://en.wikipedia.org/wiki/Command_%26_Conquer` for a description of the game. Last visited: May 2, 2012

[2] See `http://en.wikipedia.org/wiki/Civilization_%28series%29` for a description of the game. Last visited: May 2, 2012

They are filled with text, images, video, audio, animations, 3D content and an internal logic, all combined in a meaningful way. All these characteristics of digital games can be harnessed for creating powerful educational tools. Especially their encyclopedic quality provides a rich fund to communicate knowledge.

3.4 Game Design

Making good games is a very hard job indeed. Good games are fun to play from the very beginning, easy to learn, at the same time hard to master and keep the motivation high during the complete course of the game. There are few superstar designers whose reputation is known to gamers: Sid Meyer (Civilization, Railroad Tycoon), Will Wright (Sim City, The Sims) or Fumito Ueda (Ico, Shadow of the Colossus) just to name a few. In science, game design is becoming an increasingly important research topic and researchers, together with game designers, are trying hard to evolve game design into a discipline[3]. Although there is a large number of books about game design, new academic programs and the beginning of a critical vocabulary, game design hasn't yet crystallized as a field of inquiry. According to Salen and Zimmerman, the culture at large does not yet see games as noble, or even particularly useful endeavor [Salen and Zimmerman, 2003]. Despite, or actually because of this fact, the following Section covers the most important aspects about game design as a discipline. At later parts in this thesis, some central facts will be taken up again to explain the design decisions for the serious heritage games ICURA and ThIATRO (see Chapter 6 and 7).

According to Salen and Zimmerman, game design is "the process by which a game designer creates a game, to be encountered by a player, from which meaningful play emerges" [Salen and Zimmerman, 2003]. They further point out that the creation of meaningful play is the goal of successful game design. The term *meaningful play* is a central aspect of Salen and Zimmerman's work. It simply describes that (at least in a good game) the player's actions in the designed system (meaning the game) result in a comprehensible and meaningful feedback. "Meaningful play occurs when the relationship between action and outcome in a game are both discernible and integrated into the larger context of the game" [Salen and Zimmerman, 2003]. Discernible means that the result of an action is communicated to the player in a perceivable way, generally defined as *feedback*. As depicted in Figure 3.2, the player reacts on some input by making an internal decision. Based on this decision, an action is taken and the system creates the corresponding and meaningful output.

Principles of Game Design

Keeping the circle of meaningful play in mind may be helpful to get an insight in the functionality of games and how players react upon actions taken. The goal of this Section is to understand what it takes to engage players to play games for hours. Mark Prensky defines six key structural

[3]Note that a distinction must be made between *game design* and *game theory*. The latter is about making optimal choices in politics and economy and has mostly to do with psychology and math.

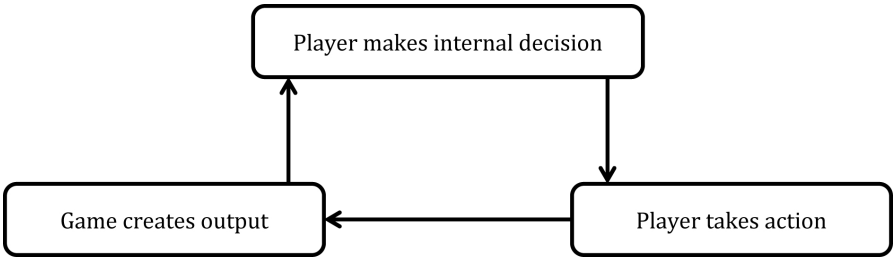


Figure 3.2: *Meaningful play*, as defined by Salen and Zimmerman [Salen and Zimmerman, 2003]

elements that make up a good game [Prensky, 2001a]. In the following these six factors are discussed to show why games lead to such strong engagement.

- Rules: As discussed in the previous Section, rules are an explicit and unambiguous part of games. Without rules, it is free play, or "playing around". Rules force us to take specific paths that lead us to goals. Furthermore, they ensure that all players take similar paths.
- Goals: According to Prensky, "we are goal oriented as species" [Prensky, 2001a]. Games push us to reach the highest score, to get to the end, to capture the flag or to beat the big boss. Achieving goals is a big piece of what motivates the player.
- Outcome and Feedback: display the player's progress against the goals. Feedback comes, when something in the game changes in response to what the player does. This usually comes in form of a numerical score, or graphically, for example when the look of one's avatar changes. The art of providing useful feedback (and thus creating meaningful play) is a highly complex task because either too little or too much can lead to moments of frustration.
- Conflict, Competition, Challenge and Opposition: These make the problems in a game the player is trying to solve. It is "what gets the the player's adrenalin and creative juices flowing" [Prensky, 2001a]. Keeping their levels in sync with the player's skills and progress is called *balancing*. As we shall see in the following Section, balancing is closely related to the concept of *flow*, another key element in game design.
- Interaction: The player interacts with the computer and thus creates a circle of feedback. In addition, interaction happens between players. While one can play alone, it is sometimes more fun to play with others (or computer-controlled characters). This social aspect brings people together, either as collaborators or competitors.
- Representation: Representation means that the game presents some kind of story, narrative or conflict. Theorists argue that representation is the essence of what makes a game, while others think it is just the "candy" [Prensky, 2001a].

These six key structural elements of games will be discussed for both of our artifacts.

To round off the list, let us have a look at the list by the *Next Generation Magazine* dealing with the question "What makes a good game" [Next Generation Magazine, 1997]. According to the article, a good game is balanced (not too hard and not too easy), creative, focused on the parts that are fun, has a memorable character, has goals that make the player care about his goals and has energy that keeps you playing. While these aspects are unquestionably important for making good games, they are after all more the results experienced by a reviewer or player than the process used to create games [Prensky, 2001a]. Mark Prensky, referring to game designer Noah Falstein, collected eleven design elements that designers use to create good games. These fundamental elements are listed in Table 3.1 on page 28.

The Concept of Flow

Because of its importance in literature, the concept of *flow* needs some special attention. It was originally defined by the Hungarian psychologist Mihály Csíkszentmihályi in his seminal work "Flow: The Psychology of Optimal Experience" [Csíkszentmihályi, 1991]. Csíkszentmihályi outlines the theory that people are most happy when they are in a state of flow, a state of concentration or complete absorption. The theory can be transferred to computer games as well. When the game's challenges are precisely met by the player's skills, she falls into flow-state. Making things too easy and the player becomes bored and stops. Too hard challenges cause frustration. Gee calls an successful learning process „pleasantly frustrating" [Gee, 2003]. The diagonal area in Figure 3.3 shows a visualization of the flow-state. The different areas of the diagram will now be explained by means of the game *Shadow of the Colossus* (SOCT).

The game was released in 2006 for PlayStation 2 (and a high-definition version for PlayStation 3 in 2011) by Japanese developers *Team Ico*. Lead developer was famous game designer Fumito Ueda, who has achieved popular cult status with his 2002 game *Ico*. Figure 3.4 shows an in-game screenshot of the PS3 version. The game's storyline focuses on a young man named *Wander* who enters a forbidden land to defeat sixteen massive colossi to restore the life of a girl named *Mono*. The game exclusively focusses on the colossi, common elements like dungeons, towns or other characters to interact with are omitted from gameplay. The player progresses in the game by seeking out and defeating each of the colossi. Most of them are located in remote areas and the search itself becomes an essential (and also emotional) element of the game. To defeat a colossus, the player has to discover its weak point. Indicated by glowing signs, they are mostly hard to reach and require Wander to climb up the colossus' body. Wander can only climb those parts of the body that are covered with fur. A central part of the game, and to some extent the reason for its fascination, is the wonderful character design, not just visually, but also the colossi's reactions to the player and their pleasantly varying level of difficulty. And this brings us directly back to the concept of flow that is exemplarily integrated into the game. The first colossus is located at a plateau that has to be climbed first. This step is thought as an in-game tutorial, teaching the player the basic controls and the rules of the game. When Wander reaches the first colossus, the player is at position 1 on the flow-chart (Figure 3.3), possessing low skills but also facing challenges appropriate to her abilities. The player experiences some initial expe-

Game Design Principle	Description
A clear overall vision	A vision is the key to make good games. The entire team must share this vision.
A constant focus on the player experience	Keep focus on making games accessible to their entire audience, including novice players.
A strong structure	The structure of the game must be carefully thought out, e.g. starting out with a small number of choices, branching out into many and tunneling back into few.
Highly adaptive	The game must be fun for a variety of players (e.g. through levels of difficulty)
Easy to learn, hard to master	The best games are those that can be learned within minutes, but provide hours or even lifetime of challenge. And high-level players can't get big benefits from easy encounters (and the other way round). This is what Raph Koster calls the "mastery problem" [Koster, 2004].
Provide frequent rewards, no penalties	Rewards are an incentive to go on. Instead of using penalties for mistakes, use rewards that decrease with time.
Include exploration and discovery	Players like to explore virtual worlds and uncover progressively various portions of the landscape.
Provide mutual assistance	One thing helps to solve another. Clues about one puzzle or task can be embedded into another puzzle or task, providing mutual assistance.
A useful interface	What is important is not a simple interface, but a highly useful one. It can also have a built-in learning curve that increases as the game goes on.
Include the ability to save progress	According to Falstein, this is a *condicio sine qua non* for good games.
Stay within the flow-state	Walk the thin line between not too hard and not too easy. See the following Section for a detailed discussion.

Table 3.1: Mark Prensky's and Noah Falstein's eleven design elements for creating good games.

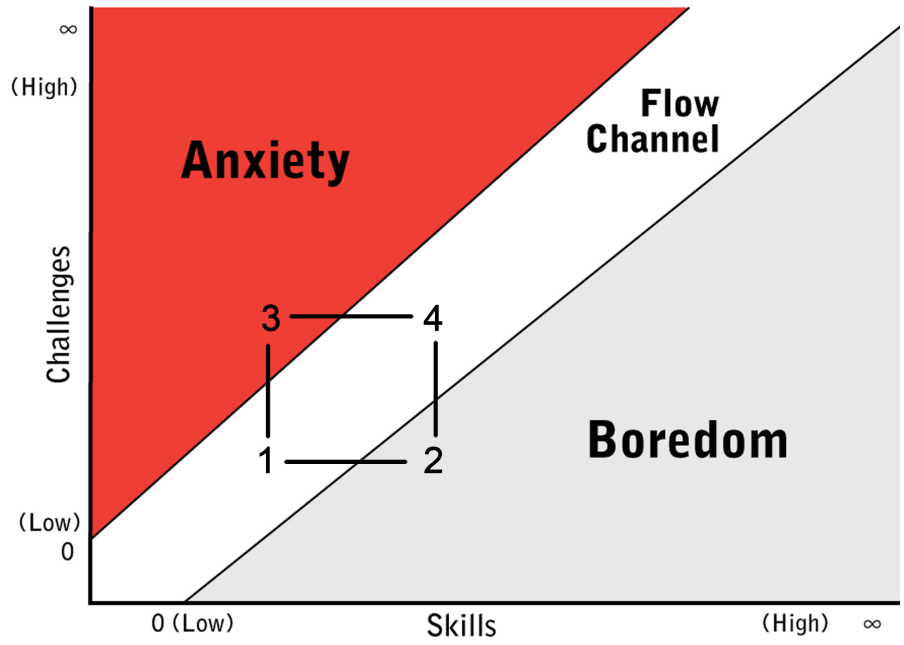


Figure 3.3: Flow-chart, adapted from Mihály Csíkszentmihályi: "Flow: The Psychology of Optimal Experience" (1991)

rience of flow. Defeating the first colossus is straight-forward and, in case of troubles, the game provides some guidance. By grabbing the furry part of the colossus' right leg, Wander climbs up to the creature's head and stabs its weak point. As the game proceeds, the player is likely to fall out of flow. If her skills exceed the challenges and the colossi are too easy to defeat, she will find herself in position 2 (boredom), an experience that does not fully engage her. On the other hand, if the sense of challenge is over-whelming her and the colossi are getting too strong, the result is a negative and intimidating experience (position 3, anxiety). When the play of the game becomes synonymously with anxiety, the experience is surprisingly similar to boredom. No matter what choices the player takes, it feels like negative outcome will always result, and choices in the game therefore feel arbitrary [Salen and Zimmerman, 2003]. Only by finding a new balance between skill and challenge the player can regain the flow-state (position 4). This is what SOCT does in a great way. Every colossus faces Wander with a new challenge. The second one, for instance, does not provide any initial possibility to climb. The player has to use his equipment (in this case the bow) to make the creature kneel down to jump up his wildly moving body. To defeat the next opponent, the player has to make use of environmental characteristics. During the course of the game, the player is taught lessons in every level and this keeps her is an enjoyable state of flow. So game designers, in the latter case Fumito Ueda and his team, are taking great efforts to teach the player meaningful lessons at the right moments and in a way that makes us retain the knowledge for a long time. For this reason, computer scientist and educator Seymour Papert thinks that "game designers have a better take on the nature of learning

Figure 3.4: Shadow of the Colossus, Team ICO (2006/2011)

than curriculum designers" [Papert, 1998]. His quotation brings us directly to a subgroup of computer games that are not exclusively aiming at entertainment.

3.5 Serious Games

To the population at large, the term *serious game* sounds like an oxymoron. The two words seem mutually exclusive, serious on the one side and a game that is expected to be fun on the other side. The term was already coined in 1970 by Clark C. Abt in his book "Serious Games", where he discussed different learning scenarios for card and board games [Abt, 1970]. He defines serious games as follows: "The oxymoron of Serious Games unites the seriousness of thought and problems that require it with the experimental and emotional freedom of active play." A more common explanation nowadays that many professionals use in this field describes serious games as a games in which education (in its various forms) is the primary goal, rather than entertainment [Michael and Chen, 2005].

Definitions of Concepts

Serious games are a branch of learning games and cover topics outside of traditional learning, like medicine, politics, art or military issues. The term is closely related to, but differs from other concepts like edutainment, entertainment education or e-learning. The following classification

of the terms is mainly based on the work "Why so serious? On the Relation of Serious Games and Learning" by Johannes Breuer and Gary Bente [Breuer and Bente, 2010].

Edutainment became a buzzword in the 1990s and aimed at blending entertainment, fun and education. While this is also the driving force behind the serious games movement, one could ask whether serious games are just a new branch of edutainment. Michael and Chen disagree and postulate that serious games "are more than just edutainment" [Michael and Chen, 2005]. As stated above, serious games go beyond traditional modes of teaching and learning. And in contrast to edutainment applications, serious games do not simply teach by rote memorization, instead they make use of a much broader potential to teach, train and inform [Michael and Chen, 2005]. Another difference is that edutainment concepts in the 1990s were in most cases designed for the target group of school children and pre-schoolers as motivators or reinforcement for classroom teaching, whereas serious games can and do reach adult audiences as well. Other concepts which are similar and partly overlapping with the category of serious games are eLearning and (digital) game-based learning. **eLearning** is a concept that is researched in various disciplines like psychology, pedagogy or computer and information science. Similar to edutainment, eLearning is a more general term that refers to any type of computer-based learning. While edutainment is generally not bound to any specific medium, e-learning is coupled to the use of computers. It does not imply any need for entertainment and fun in the learning process. The central advantage of e-learning is that it enables remote learning and learner groups distributed over different locations as well as nonparallel or asynchronous and flexible learning. So also serious (digital) games can be seen as subtypes of e-learning. Another concept that overlaps with serious games is that of game-based or **digital game-based learning** (DGBL) that Marc Prensky uses in his book of the same title [Prensky, 2001a]. Game-based learning is a partition of serious games including the use of any type of games (e.g. board games, card games, sports and also digital games) for learning and educational purposes. (D)GBL is the section of serious games, which incorporates education and learning as the main or sole purpose, whereas serious games also have application fields outside of education and learning (art, therapy, advertising etc.). Figure 3.5 summarizes the relations of edutainment, (digital) game-based learning, e-learning and serious games, as defined by Johannes Breuer and Gary Bente [Breuer and Bente, 2010].

Topics and History

A strict classification is very difficult because many serious games include more than one type of educational content. In 2008, Ritterfeld et al. presented a field study that examined 650 free available English speaking serious games in which they classified these games [Ritterfeld et al., 2009]. According to the study, 63% of the investigated games are related to a primarily academic educational context like languages, mathematics, physics or chemistry. 14% is related to social change issues, such as politics, world poverty or saving the environment. The rest is evenly distributed on occupation, health, marketing and military. Since the beginning of serious gaming, the military and the government have been the primary source of funding. The military has a long history of using games and simulations to teach recruits and officers. One example is the use of flight simulators: According to Michael and Chen, it took over two decades before they were accepted as a viable way to train new pilots. Today they are considered a necessary step in pilot

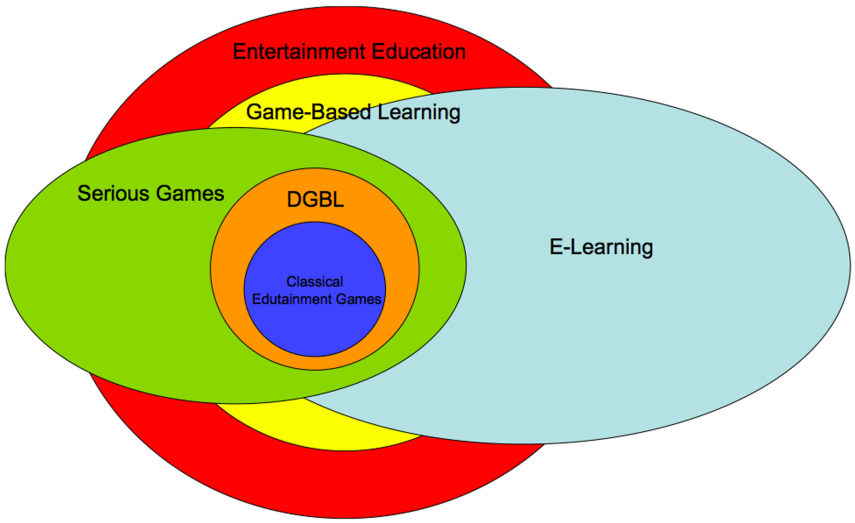


Figure 3.5: The relations between serious games and similar educational concepts, Breuer and Bente (2010)

training [Michael and Chen, 2005]. The use of war-games as an inexpensive way, regarding men and ressources, to train has an equally long history. Finally, in 2002, the U.S. Army released an unprecedented government-funded first-person shooter game. *America's Army: Operations* was conceived and openly publicized as an army recruiting and communications tool. It was created on the then-current Unreal 2 engine, a costly professional grade game engine and released for free on the army's website. Within the first six months, over million users had registered, of which over 600,000 had completed the game's basic rifle marksmanship and combat training [Bogost, 2007]. America's Army has proven to be one of the most successful military recruiting tools ever and is often cited as the first official serious game. In the following years lots of remarkable serious games have followed, covering a wide range of topics. See Chapter 5.1 ("Related Work") for an collection of examples.

Serious Games in Practice

As defined by Michael and Chen, "serious games use the artistic medium of games to deliver a message, teach lessons, or provide an experience" [Michael and Chen, 2005]. The use of serious games for classroom teaching is much discussed and teacher's causes for concerns about a lack of examples of how games can be integrated in the curriculum are absolutely plausible. Additionally, many teachers worry that school computer are insufficient to run modern serious games. As we will see, the last concern can be dealt with because serious games do not demand the same level of technological "wow" factor as commercial games do [Michael and Chen, 2005]. They don't require the prettiest graphics, are built in much smaller teams with less effort, and use existing technologies with proven content pipelines. As Michael and Chen say, "bigger is not always better in Serious Game development" [Michael and Chen, 2005]. According to their

survey among 60 serious game developers, over 73% of the teams are made up of only one to ten developers. And two-thirds of the most recent serious games projects were finished within a one year time frame. So, in direct comparison to commercial off-the-shelf games, serious games have no need for expensive resources and can be released within much shorter development cycles. In fact, the success of a serious game is defined by the way the learning content (or message) is integrated into the game. The main problem is still a lack of clear guidelines how to design successful serious games that teach a desired subject in a highly motivating way. And why should teachers take the risk to be the first one to experiment with novel teaching methods? The main argument in favor of integrating serious games in the curriculum is that the element of fun (that is considered as important or very important by 80% of the respondents) is a powerful motivator to learn for children, even at home, learning on their own. Eric Klopfer, cited by Michael and Chen, referred to the content part of serious games as the "Trojan horse". In other words, as the student plays the game she learns the desired subject, whether the student is intended to or not [Michael and Chen, 2005]. In the next Chapter we will investigate different theories in literature why game are such powerful mediators of knowledge and how educators can harness this power for teaching purposes.

Positive Impact Games

Another very recent field of research deals with games that have a positive impact on society. The term *Positive Impact Games* was originally discussed on the "Meaningful Play Conference" and the "Montreal International Game Summit'" in 2008 and describes games that result in positive changes in the real world. According to the *Positive Impact Games Special interest Group*[4], these positive impacts include furthering social interaction and assimilation, providing education to young children and adults and encouraging personal discovery.

Two projects that were developed in cooperation with Vienna University of Technology are *YourTurn! The Video-Game*[5] and *Landspotting*[6]. YourTurn is a music-based Facebook game for Viennese youth that brings together people of different ethnicity, gender and place of residence who normally would not be in contact with one another [Kayali et al., 2011]. Players engage in battles on Facebook by selecting snippets of Youtube videos, which they append to a mutual DJ mix. Playing against each other leads to a shared and creative result made by two players who previously did not know each other. The second project, Landspotting, harnesses crowdsourcing and social gaming approaches for the in-situ validation of land cover products. Current ecosystem and land-use science lacks crucial accurate data, for example to determine the potential of additional agricultural land available to grow crops in Africa. Landspotting creates a global network of volunteers contributing geospatial validation data and in-situ information and aims at adding social game components to widen this community of contributors. Both games have the honorable goal to evoke positive changes in the real world and support Jane McGonigal's opinion that "games can make a better world" [McGonigal, 2010].

[4] `http://positiveimpactsig.wordpress.com/`, last accessed: May 16, 2012

[5] `http://igw.tuwien.ac.at/seriousbeats/Serious_Beats/About.html`, last accessed: May 16, 2012

[6] `http://www.landspotting.org/`, last accessed: May 16, 2012

CHAPTER 4

Digital Game-Based Learning

"Play is our brain's favorite way of learning."
(Mark Prensky, 2003)

In the last Chapter we defined digital game-based learning as a subgroup of serious games that use digital games for learning and educational purposes. Originally coined by Mark Prensky, the term can be simply defined as "any marriage of educational content and computer games" [Prensky, 2001a]. Based on the theoretical findings on cognitive styles and game design, this Chapter continues to investigate the educational power of video games. We will start with a brief history of learning, followed by some core concepts of cognitive science. In Section 4.2 we will investigate the current situation of learning and teaching approaches to trace possible drawbacks and to outline new ways of learning and teaching that may comprise some potential to excite people from the games generation. To understand the mechanisms through which games teach, we will have a close look at the theories of Mark Prensky, James Paul Gee and other researchers in this area. We will conclude by summing up the success factors of digital game-based learning.

4.1 A History of Learning

Changes in technology and society have lead to a constant evolution of teaching and learning paradigms. In his book "Digital Game-based Learning", Mark Prensky sketches a brief history of learning and technology [Prensky, 2001a].

The first archaic form of training was a process of imitation and coaching. Learners were taught by receiving proper instructions, followed by a repetitive practicing process. This form of learning requires good coaches and it still proves to be effective at present time (e.g. when learning an musical instrument). The next important step was the development of spoken language. From now on people were able to ask questions to check if the learner answers in a way that shows understanding. This approach was brought to perfection by Greek philosopher

Socrates and his dialectic method of questioning. The next step in the evolution of learning was the invention of literacy, writing and reading. As a result, the myths, stories and theories of the greatest poets and thinkers did not need to be told or memorized anymore: Learner could finally read their own thoughts, and thoughts of others. The knowledge of whole cultures was carried together in libraries and thus preserve for later generations. The next big thing that pushed learning forward was the invention of printing press that enabled a much quicker distribution of knowledge. For the first time educational materials could be distributed to anyone who wanted them. And along with that came the need to teach more people a basic level of literacy. The next significant change came in form of the industrial revolution which led to standardization of the school system and, in succession, to the need for testing people to check their knowledge on an uniform basis. Today, we all experience the latest step in evolution of learning, caused by the technological revolution. The interactivity of computers and the constant availability of the Internet made learning a completely novel experienced that changed the ways we think significantly. According to Prensky, written language became less dominant and was mainly replaced by text-on-screen [Prensky, 2001a]. Furthermore, the linear organization of things we choose to learn about was supplemented by a random access organization and active media, such as games and the Internet, rather than passive ones (like books or TV). Speed in general increased, leaving less time and opportunity for reflection. These changes happened within a few years, too fast for our teaching system to react appropriately. Prensky ironically says that "we know more about how to improve the use of diapers than our brains" [Prensky, 2001a]. What he means is that relative little research on different learning styles is actually done. Researchers criticize that most schools (and other educational systems) still stick to behaviorist learning theories, as already proposed in the beginning of the 20th century. Behaviorists like Edward Thorndike and Burrhus Frederic Skinner emphasize that learning takes place via repetition and reinforcement. They have later been accused of ignoring the private, mental process inherent in individual human beings, leaving no room for human subjectivity [Bogost, 2007]. Behaviorist's strict concept of direct instructions and repetition may also have contributed to today's negative attitude towards learning, which is often perceived as a painful experience and the opposite of fun. But learning does not have to be painful. Research in cognitive science found out that other ways of learning have proven to be more successful and more motivating. According to James Paul Gee [Gee, 2003], humans don't just store experiences in in their minds "as is". Rather they edit them according to their interests, values, goals and socio-cultural memberships, foregrounding important, and backgrounding less-important information. Furthermore, "it is the connections or associations that people make among their experiences that are crucial to learning, thinking and problem solving" [Gee, 2003]. In this context we are talking about the constructivist learning theory of Swiss development psychologist Jean Piaget. Constructivists believe that a person learns best when he or she actively *constructs* ideas and relationships in their own minds based on experiments, experiences and past knowledge, rather than simply being told information. In his 1963 work "Cognitive development in children: Development and learning" [Piaget, 1964], Piaget says:

> *"Knowledge is not a copy of reality. To know an object, to know an event is not simply to look at it and make a mental copy, or image, of it. To know an object is to act on it. To know is to modify, to transform the object, and to understand the*

process of transformation, and as a consequence to understand the way the object is constructed." [Piaget, 1964]

Piaget's approach, which is closely connected to John Dewey's idea of the "active learner", frees the process of learning from being a cumbersome and passive endeavor. He makes learning an experimental and playful process that is mainly driven by the learner's own curiosity. Piaget's work provides the basis for later approaches on learning by means of (digital) games. Related to constructivism is the idea of constructionism, proposed by Seymour Papert in "Constructionism: A new opportunity for elementary science education" [Papert, 1986]. Papert says that learning can happen most effectively when people are active in making tangible objects (artifacts) in the real world, such as building a model of a bridge to learn about statics. The importance of both approaches, constructivism and constructionism, will be explained in Chapter 6 and 7 using the examples of our artifacts ICURA and ThIATRO.

Generally spoken, constructivism (and constructionism) emphasize the importance of providing information inside a context, in which the learner can construct ideas and relationships. According to Gee, "one good way to make people look stupid is to ask them to learn and think in words and abstractions that they cannot connect in any way to images and situations in their embodied experiences in the world" [Gee, 2003]. He adds that we regularly do this in schools. Gee's harsh critique will be the subject of the next Section.

4.2 The current situation

Seymour Papert, accompanied by a vast number of children and teenagers, shares the opinion that school is boring - boring compared to TV and computer games [Papert, 1986]. Traditional classroom teaching relies on behaviorist learning strategies. As discussed in the last Section, students practice within question/answer frames, responding and receiving either positive or negative immediate feedback. Prensky calls this approach "tell-test" [Prensky, 2001a], which works by telling the learner information and testing her afterwards. Tell-test is the basic teaching method used in schools, corporations, colleges and even in almost all e-learning experiences. Prensky voices criticism by saying that tell-test is failing to do the job it used to do because the world of the learner has changes so dramatically and kids have totally outpaced their parents [Prensky, 2001a]. They see themselves as creators and doers, but the prevalent situation fails to excite people from the games generation. He believes that our whole learning system is "breaking down" and we must go away from telling facts to teaching through "discovery, interaction, and all above, fun". As we have seen in Section 3.2 on cognitive style changes, learners want to learn at their own pace, following their own (interactive) style. The tell-test approach offers absolutely no choice in the curriculum and how content is presented to the learner. Gee says, school does not encourage "situated and embodied thinking and doing" [Gee, 2003]. By this he means that words and meanings usually float free and the learners cannot do anything with these words. He proposes teaching by connecting information to *situated experiences*. The learner should be able to connect the information to areas of her life, she is familiar with. Prensky further harshly criticizes today's situation in schools. He says: "If our training or school is

boring to our students, it is entirely our fault as educators. Blaming anyone else - especially our students - is like a doctor blaming his patients for getting sick" [Prensky, 2001a].

There are dozens of reasons why there are no changes in the current situation. First of all, encouraging reformations costs money and decision-makers simply don't know what today's learners want. And as Gee experienced it, children do find this sort of instructions meaningful and compelling, usually because they trust that it will lead them to accomplish their goals and have success in later life [Gee, 2003], And it sort of works as it is right now, even though in a way that is in need of clear improvements. And many educators say that there simply isn't enough time to teach everything in ways that make sense in terms of situated meaning and embodied action [Gee, 2003].

4.3 New Ways of Learning

We can see that there are no significant progresses in learning technologies but, with regard to computer games, we have made unbelievable advances in the entertainment sector. Already in 1970, Clark C. Abt considered traditional games for integration in school teaching [Abt, 1970]. He noticed that students who are not motivated to learn in school are frequently highly motivated in other activities., for example sports. He explains this by the "frequent lack of drama" in the school environment [Abt, 1970]. Within a game-like learning approach, these children, who are often shy and withdrawn in face-to-face situations, become surprisingly active and communicative because "it is only a game". The possibility of losing one's face in accepted. So Abt already laid out the vision of reforming education through games 40 years ago. With the rising success of digital games, we have a powerful mediator on hand that combines engagement and entertainment in a way that makes sense to learners. On the downside, one could remark that there simply is no time in school to use games. Therefore, as Prensky proposes, the best way to make a difference is to relocate their usage from school to the student's home:

> *"If the kids are going to use their programs at home, they have to be able to beat the other things that interest children - television and video games - because at home the kids can choose to do is, whereas in school you can make them do it."* [Prensky, 2001a]

Prensky's remarks mostly refer to the usage of (learning) games for children. Nowadays, keeping in mind that the average player is 37 years old [Entertainment Software Association, 2011], his ideas and visions can be extended for harnessing the power of educational games for everyone, and every generation. Especially serious games, providing education outside of traditional topics, offer an opportunity for a lifelong learning process.

Digital game-based learning makes perfect sense by teaching in ways that other methods seldom do. It appears that the extraordinary level of engagement is caused by fun in the learning process. Fun creates relaxation and this in turn enables learners to absorb information more easily. And motivation enables them to put forth effort without resentment [Prensky, 2001a]. Figure 4.1 depicts the correlation along the two principal dimensions learning and engagement in digital game-based learning. Note that an application providing really high learning potential

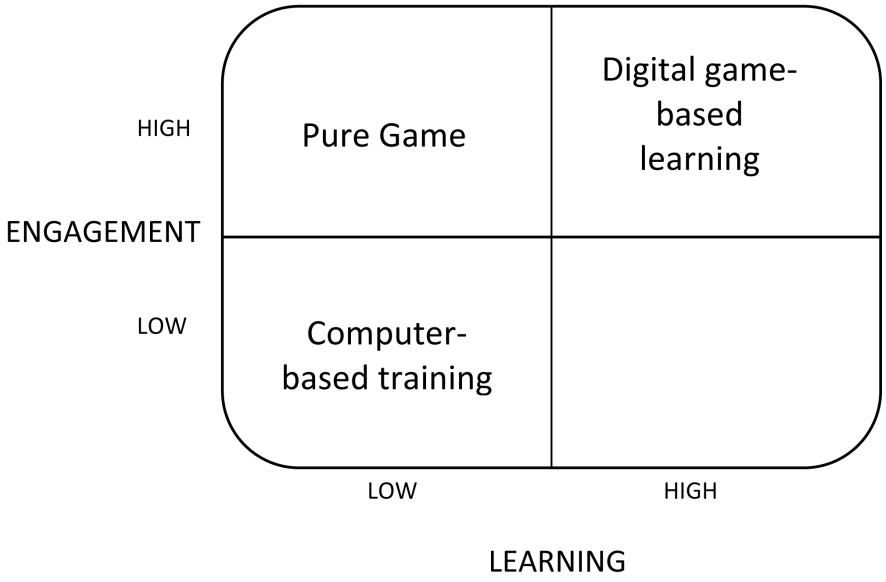


Figure 4.1: Correlation between learning and engagement for Digital game-based learning (Prensky, 2003)

with low engagement doesn't exist and is therefore considered as "null" category. As we will see in Chapter 4.5 about J. P. Gee's theories, high learning potential automatically leads to a higher motivation.

In summary it can be said that, in comparison to the conventional tell-test technique, the student's involvement with games is significantly higher. Abt cites a student who said: "You can learn things by reading, but game learning is more fun, and what have you got against making it fun to learn" [Abt, 1970].

4.4 The Promise of DGBL

It might well be that the school of the future makes extensive use of digital game-based learning. But, considering the present situation, a lot of persuading has to be done to satisfy the last critics. Clark C. Abt deals in his 1970s book "Serious Games" a lot with skeptical statements about playful learning. He raises the concern of many teachers that games take more time to teach certain concepts than other methods do [Abt, 1970]. Abt, in return, criticizes the sceptic's attitude to equating learning with the ability to reproduce a certain set of facts on a given amount of time. "Rote memorization" produces knowledge to be reproduced on a test, but never to be considered again afterwards. This circumstance is often deprecatingly referred to as "bulimic learning" - learning of short duration and little relevance to solving real problems [Zorek et al., 2010]. Abt says that "the only problem solve is that of finding the minimum effort needed to respond to a test" [Abt, 1970]. It is all about the creation of long-term knowledge that perhaps

in ten years will still be remembered - knowledge and insights that, in the future course, lead to much better decisions in life. This becomes increasingly important with regard to serious games that, as we have learned in Chapter 3.5, often deal with issues of social importance.

One major promise of digital game-based learning is that it can play an important part in learning material that is not intrinsically motivating but which has to be learned. This can be material that is dry, technically challenging, extremely difficult or aiming at an target audience that is hard to reach [Prensky, 2001a]. Prensky emphasizes that DGBL creates a lasting educational impact that will be remembered a long time and the possibility to share learning experiences world-wide on the Web, bringing together millions of learners. By the time of writing this thesis, companies are starting initiatives to induce educators around the world to provide their interactive textbooks and lectures on freely accessible platforms[1]. This approach is definitely a step into the right direction, although most of the uploaded material does not yet integrate any game-like approaches.

4.5 How Games Teach Us

In this Section we will have a detailed look into the core mechanisms of digital games and why they are considered by several scientists, with J. P. Gee leading the way, as "pure learning machines". Gee presents his groundbreaking theories on the correlation of pedagogy and digital games in the book "What video games have to teach us about learning and literacy" [Gee, 2003]. Note that Gee is mainly talking about commercially successful games and not games with an explicitly educational content. His basic statement is that didactics can learn a lot from the ways how games teach their players and not the other way round. The following paragraph gives a brief summary of Gee's theories.

In order to complete a computer game, children have to pass through a self-directed and intrinsically motivated learning process, which's complexity outperforms a learning process guided by school curriculum by far. Children are much more successful and efficient with learning the rules of a game than learning for school. Gee traces this circumstance to some sort of natural selection that computer games have to pass through on the free market. Only when a game offers interesting and motivating challenges, and only when the game offers optimal support for learning the skills to master these challenges, then it will be commercially successful. On grounds of this deterministic assumption, Gee sees successful computer games as ideal objects of study to identify new and better didactic paradigms, as well as their practical application for use in schools. Thereby, Gee disproves prevalent theories on digital game-based learning. It is no longer didactics that form the basis for developing learning games, in fact it is computer games that underlie progression in didactics.

As the book continues, Gee analyzes various games and formulates a total of 36 foundational principles. According to him, these principles characterize successful games and would also be conceivable for practical use in schools. Many of these principles integrate the term "semiotic domains". By this, Gee means a sector of social life that isolates itself by means of communi-

[1] For example *Apple in Education*, http://www.apple.com/education/, last accessed: Feb 28, 2012

cation and the symbols that are used (such as language, writing or signs). To give an example, *natural scientists* use a language that differs a lot form common everyday speech. Only people, who are acquainted with the scientific field of natural science (or, as Gee calls it, people who are "socialized" in the field), are able to understand their language with all its subtleties. They therefore belong to the same semiotic domain and are part of the "affinity group". There is an endless range of semiotic domains, including (but certainly not limited to) first-person-shooters, rap music or art history. The characteristics of art history will be examined in detail in Chapter 7.1. In order to successfully teach a topic, so Gee, teachers have to be introduced, and therefore socialized in the corresponding semiotic domain. While this socialization process stands at the beginning of every successful computer game, an analogue process is completely missing in traditional classroom teaching. As a selection of Gee's 36 principles, we will provide two of them here:

Principle 1: All aspects of the learning environment (including the ways in which the semiotic domain is designed and presented) are set up to encourage active and critical, non passive, learning.

Principle 4:: Semiotic Domains Principle: Learning involves mastering, at some level, semiotic domains, and being able to participate, at some level, in the affinity group or groups connected to then.

Gee further defines the terms *situated and embodied meanings*. To make sense of the information (meaning the learning content), it has to be integrated into the emerging plot and virtual world the player is discovering. Consider a game that lets the player search for a code of some sort. The code, at this point, just has a decontextualized, general meaning and appears to the player of very limited interest. She will not attribute particular importance to this code and thus forget it. But as soon she finds something (e.g. a safe) that it can be used on to some good effect, the numbers take on situated, embodied, action-oriented meaning and the code will be remembered. As James Paul Gee suggests, "Let the player experience a delicious moment of wonderfully embodied and situated meaning" [Gee, 2003].

The Case of *Half-Life* and *Dark Souls*

In his 2003 paper, Gee gives a wonderful example of successful learning mechanisms in the first-person shooter game Half-Life (Valve Corporation, 1998). The game repeatedly confronts the player with a similar type of problem, for example enemies like the *headcrabs*, until she has achieved a routinized, taken-for-granted mastery of certain skills. Then the game introduces a new challenge, for instance a new type of enemy or boss, which forces the player to rethink their own taken-for-granted mastery and to combine their old skills with new ones. The player starts generalizing her knowledge and puts everything she has learned so far into practice. And this is exactly what causes a lasting learning experience.

Another often cited example is the action role-playing game *Dark Souls* (From Software, 2011), which has been reviewed as one of the hardest games in recent video game history

[Bakalar et al., 2011]. It contains very intense and challenging boss fights. The game mechanics don't really allow the player to improve her character (e.g. by leveling up) up to a point the boss fights could be considered trivial. In order to defeat a boss the player generally needs to exactly memorize his movements, attacks, choreography and everything else related to that particular boss, by engaging him several times. This continues until she's finally able to flawlessly read all of the bosses actions to react accordingly each time, over the course of several minutes. So, instead of improving character, players have to actually improve on themselves, by disciplined repetition, to complete the set goal and grab their reward. The whole process is very similar to a behavioral teaching scenario.

To come back to school education, the two examples show us that it doesn't make sense to confront children with easy cases. The issue is starting them with cases that are basic or fundamental in the sense that they lead the learner to discover and practice what are, in fact, "fruitful patterns and generalizations" [Gee, 2003]. These patterns allow the learner to make real progress in the domain and can serve as the correct basis of good guides for more complicated patterns and generalizations that need to be discovered later by confronting more complex and less-basic situations and cases. This concept of generalizations is considered as one central design principle for the practical work of this thesis. The two games from above furthermore allow the player to practice in the virtual world. Playing a good video game, so Gee, requires the player to engage the following four-step process [Gee, 2003]. We followed this process when designing the artifacts for this thesis.

- The player must *probe* the virtual world, which involves looking around the current environment clicking on something, or engaging a certain action.
- Based on reflection after probing, the player must form a *hypothesis* about what something (a text, object, artifact, event, or action) might mean in a usefully situated way.
- The player reprobes the world with that hypothesis in mind, seeing what effect she gets.
- The player treats this effect as feedback from the world and accepts or rethinks her original hypothesis.

4.6 Design Guidelines

Few research has been done to design clear guidelines for digital game-based learning applications. In fact, it is very hard to formulate one detailed set of rules that fits all types of educational games. Instead, scientists concentrate on shaping frameworks that provide some general guidance with the design of learning games. As an example, Linehan et al. [Linehan et al., 2011] defined some loose guidelines that demonstrate actual steps to put the concept of digital-game based learning into practice. For this purpose they adapted principles of the *Applied Behavior Analysis* and applied it to gaming. Applied Behaviour Analysis is based on the findings in the field of behavioural science. ABA is adaptive to the performance of each individual, and intends to maximize learning results by setting targets, that learners can achieve through discipline, high

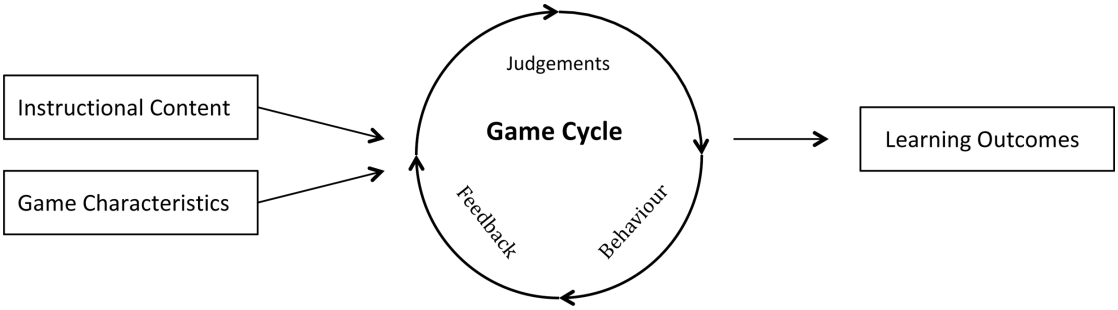


Figure 4.2: Input-Process-Outcome Game Model, Garris et al. 2002

performance and repetition, if necessary. The teacher's role in such a setting resembles rather that of a coach or supporter. Garris et al. introduced a model of game based learning that shows in a very simplified way how learning can be improved by a game based approach [Garris et al., 2002]. Figure 4.2 visualized their concept. The Instructional/educational content (the first part on the input side) shows the content the player absorbs during the process of gaming. To actually create an educational game, the educational content is combined with game characteristics. Once these two components successfully merge, they trigger the game cycle consisting of judgments, behavior and system feedback. The game cycle means nothing else than repeated self-motivated learning, compared to traditional learning which is more of a one directional experience. Therefore creating a working game cycle is essential.

Kiili describes an experiential gaming model that is based on experiential learning theory, flow theory and game design [Kiili, 2004]. The model stresses the importance of providing the player with immediate feedback, clear goals and challenges that are matched to her skill level. The experiential gaming model can be used to design and analyze educational computer games. However, the model works only as a link between educational theory and game design and does not provide the means to a whole game design project.

4.7 Learning Techniques in DGBL

We want to conclude this Chapter with Mark Prensky's list of interactive learning techniques in games [Prensky, 2001a]. Some of these principles from Table 4.1 have been integrated into the design of the games presented in this thesis.

Learning Technique	Description
Practice and Feedback	It can be an excellent way of learning things that require lots of repetitive practice, although not the most interesting form of learning on a computer.
Learning by doing	Computer games are especially good at fostering interaction, exploration, discovery and problem solving.
Learning from mistakes	Doing and failing - or trial and error - is a primary way to learn in games.
Goal-oriented learning	The goal in a game, which are usually considered as worth reaching, are what give the incentive to keep on playing.
Discovery Learning & "Guided Discovery"	It is based on the idea that you learn somehting better if you find it out for yourself, rather than have it told to you.
Task-based Learning	A variation of learning by doing. Task-based learning goes straight ahead to a series of tasks that build on each other and gradually increase in difficulty.
Question-based Learning	Traditionally associated with quiz or trivia games, they easily grab people's attention.
Situated learning	The learning is set in an environment that is similar or identical to where the learning material will be applied in the future.
Role-playing	Role-playing is often used in interactive training, particularly for "soft skills".
Coaching	Coaches are often integrated into the learning program and come in form of characters that you meet as you are exploring the environment.
Constructivist Learning	As discussed in Chapter 4.1, a person learns best when she actively "constructs" ideas.
"Accelerated" (Multisensory) Learning	Learning that involves multi-sensory experience.
Learning Objects	If one can design pieces of content and certain interactions that are independent, then she can link them together in whatever order is needed (just like in object-oriented programming).
Intelligent Tutors	An intelligent tutor looks at the learner's responses and tries to decide why she made the error and gives specific feedback.

Table 4.1: Interactive learning techniques in games, Mark Prensky (2003)

CHAPTER 5

Serious Heritage Games

The last two Chapters covered the theoretical basis of game design, serious gaming and games for teaching purposes. We will now go further into the question, if games can be harnessed to communicate knowledge of an area that has been widely untouched by digital entertainment media. As announced in the introduction, we are talking about the field of *cultural heritage*. The term "cultural heritage" can be defined as "the legacy of physical artifacts and intangible attributes of a group or society that are inherited from past generations, maintained in the present and bestowed for the benefit of future generations."[1] In order to pass on cultural heritage artifacts to later generations, we must take precautions in the present to guarantee high-quality preservation. Methods of presenting these artifacts (e.g., in museums) are developing in a changing world, and professionals must adapt to these changes. This calls for new ways to raise children's and young adults' interest in their cultural heritage because they are the next in line to carry out high-quality preservation of artifacts. Otherwise, we risk losing our precious cultural assets. In their 2010 paper, Anderson et al. investigated the usage of (serious) games for cultural heritage purposes [Anderson et al., 2010]. Their state-of-the-art report on, what they call, *serious heritage games* covers theories, methods and technologies used by developers in the field and brings up the following consideration:

> *"Although the widespread use of gaming for leisure purposes has been well documented, the use of games to support cultural heritage purposes, such as historical teaching and learning, or for enhancing museum visits, has been less well considered."* [Anderson et al., 2010]

This gap in research also motivated the research behind this thesis. All games are part of culture. For example, the Olympics are not just a series of sporting events, but a content in which global politics infuse the play of the game an many levels [Koster, 2004]. We do belief that games have the power to reflect, and thus teach, culture to some degree. According to Salen

[1] Definition by the UNESCO World Heritage Centre, `http://http://whc.unesco.org/`, last accessed: Feb 29, 2012

and Zimmerman, "games are designed objects that engage culture on several levels" [Salen and Zimmerman, 2003]. What they mean is that games are capable of reflecting culture because they are objects produced and played within culture at large. Games depict images of gender (e.g. *Tomb Raider*, Core Design 1996), as well as portrayals of race and class (e.g. *Street Fighter*, Capcom 1987). The cultural dimensions of a game are part of the game itself, reflecting values and ideologies of surrounding contexts. Salen and Zimmerman say:

> *"Another way of saying games reflect cultural values is that games are social contexts for cultural learning. This means that games are one place where the values of a society are embodied and passed on. Seeing games as social contexts for cultural learning acknowledges how games replicate, reproduce, and sometimes transform cultural beliefs and principles. Games reflect the values of the society and culture in which they are placed because they are part of the fabric of that society itself."* [Salen and Zimmerman, 2003]

So, we can see that our culture and cultural belonging influences the design of our games. For this thesis, we invert this fact and investigate how game design can influence our views on culture itself. Can we use games to gain insights in communication, aesthetics, symbols, and other areas of tangible and intangible cultural heritage that seem so intertwined with games?. Already in 1970, Clark C. Abt saw the possibility that games can reduce cultural barriers [Abt, 1970]. And with the dramatic advances in digital technologies (especially computer graphics hardware) we have tools on hand to raise the interest in our cultural heritage as never before. Modern game technologies allow real-time interaction with virtual heritage scenarios, reconstructions of ancient sites, or museums, even online using basic consumer machines. The following Section provides an extensive collection of related projects on serious heritage games (with no claim to completeness).

5.1 Related Work

The summary of related work is categorized into four types of computer-game-like applications. First of all, we will start with serious games in general to get an impression of the wide range of topics they can cover. Afterwards, we will directly step into the field of cultural heritage and deal with prototypes and demonstrators. These applications are mostly visualizations of historical sites that not yet integrate game-like components. We will then have a look at modern museum games that are integrated into an existing exhibition. These subgroup of games provides a rich source of novel gaming approaches for cultural heritage that successfully enthuse its audience. In the end, we will have a brief overview of commercial serious heritage games.

5.2 Serious Games

In their book "Serious Games", Michael and Chen propose the following thematic classification [Michael and Chen, 2005]: Military Games, Government Games, Educational Games, Corporate Games, Healthcare Games, Political and Religious Games. This Section is organized according

to this classification and gives an overview of recent projects from every subdomain, with special focus on the field of cultural awareness. The findings were also published in the paper "Design and evaluation of a Serious Game for immersive cultural training" for the Conference on Virtual Systems and Multimedia, 2010 [Froschauer et al., 2010].

Educational Games

Educational Games look for ways to use Serious Games as an effective teaching medium. In literature there are many examples for Educational Games. *SeaGame* [Bellotti et al., 2009] is a massive multiplayer online game (MMOG) for high-school students that was designed to promote best practices in sea-related behaviors, such as sailing or doing beach surveillance. The main goal of SeaGame was to embed the educational content in a meaningful, homogeneous and compelling whole, where the player's enjoyment takes center stage. *Wu's Castle* [Eagle, 2009] is a 2-dimensional role-playing game where the students interactively construct C++ code to solve in-game problems. Findings show, that Wu's Castle is more effective than a traditional programming assignment for learning to solve problems on loops and arrays. The pervasive game *Power Agent* [Gustafsson and Bång, 2008] is aimed at both teenagers and their parents and teaches ways to reduce energy consumption at home. In contrast to the projects mentioned above, Power Agent is a mobile-phone based game that transforms the home environment and its devices into a learning arena for hands-on experiences with electricity usage. Many serious games can be found online to reach a wide audience. *Anti-Phishing Phil* [Sheng et al., 2007] is an online game that teaches users good habits to help them avoid phishing attacks. A study showed that users who played the game were better able to identify fraudulent web sites compared to those, who read tutorials about phishing. Concerning cultural heritage there are two projects we want to mention here: *Travel in Europe* (TiE) [Bellotti et al., 2008b] and *Second China* [Fishwick et al., 2008,Henderson et al., 2008]. TiE aims at implementing an innovative means to promote and divulge cultural heritage. In an online environment the user interacts within virtual representations of European cities and accomplishes missions in a treasure-hunt manner. Trial games, small and simple 2D games, concern the local artistic heritage and focus the player's attention on a particular item. The Second China island in the virtual world of Second Life is a 3D space in which cultural content is experienced virtually by the user. From a central web-based portal, the user enters the learning environment and choses between a 2D traditional web-based route and a 3D immersive experimental route. In different virtual learning scenarios Second China communicates respect and understanding of the target culture.

Corporate Games

Corporate Games deal with industrial applications for training, simulation, further education and skill enhancement in general. In *CyberCIEGE* [Greitzer et al., 2007], users spend virtual money to operate and defend their networks. CyberCIEGE is a security training within a game-based environment that covers the the significant aspects of network management and defense. In 2009 the game *World of Subways Vol. 1 The Path* was presented with the Serious Games Award for

Best Corporate Game [2]. The player slips into the role of a train conductor and learns the complex procedure of operating a subway within a realistic training environment.

Political and Religious Games

Political and Religious Games often intend to spread a message instead of teaching the player. There are few publications about this subject area, but a collection of games can be found at `www.socialimpactgames.com`. A successful example is *Dafur is Dying*[3], released in 2006. The flash-based browser game demonstrates what it is like for more than 2.5 million people who have been displaced by the crisis in Sudan.

Healthcare Games

Many Serious Games are being used in healthcare for treatment, recovery and rehabilitation. *SMILE* (Science and Math in an Immersive Learning Environment) is an immersive learning game that employs a fantasy 3D virtual environment to engage deaf and hearing children in math and science-based educational tasks [Adamo-Villani and Wright, 2007]. SMILE is the first bilingual immersive learning environment for deaf and hearing children. [Marsh et al., 2005] and [Wong et al., 2007] describe the experiences of the *2020Classroom*, an on-going project to develop a 3D learning environment through a game called *Metalloman* to teach bioscience concepts to undergraduate students. Students "travel" and "perform" vital functions to complete mission objectives and interact with the human body in a playful way. Similar to this is the game *Immune Attack* [Kelly et al., 2007] that combines a realistic 3D depiction of biological structure and function with educational technologies for teaching immunology to high school students.

Government Games

A Government Game simulates politics of a nation, such as the creation of domestic political policies or political campaigns. *FloodSim* [Rebolledo-Mendez et al., 2009] is a serious game created to raise awareness of the flooding issue, flood policy and government expenditure in the UK. In this online game the player takes on the role of a flood policy strategist employed to implement a selection of strategies for addressing the risk of flooding based on a pre-defined budget.

Military Games

The military has been the primary source of funding for Serious Games [Michael and Chen, 2005]. As mentioned in Chapter 3.5, the first version of *America's Army* was released in 2002 and began a revolution in thinking about the potential role of video games for non-entertainment domains [Zyda, 2005]. Soon the game was successfully used as soldier training and recruiting tool. In this context Zyda created the term "first person education" [Zyda, 2005]. Two very elaborate examples for Military Games are *Tactical Iraqi* and *Virtual Iraq*. Tactical Iraqi was

[2] `www.seriousgamesaward.de`, last accessed: March 5, 2012

[3] `http://www.darfurisdying.com/`, last accessed: March 29, 2012

designed to accelerate a learner's acquisition of spoken Arabic to assist soldiers into volatile tactical situations. Virtual Iraq is a virtual reality simulation intended to reduce the effects of post-traumatic stress disorder [Johnson et al., 2007, Losh, 2006]. One is pedagogical, and the other is therapeutic. To come back to games that are connected to the thematic range of this thesis, Zielke et al. deal with a project that integrates the field of cultural heritage, however, with military background. The 3D Asymmetric Domain Analysis and Training (3D ADAT) model is a recursive platform for the development and visualization of dynamic sociocultural models [Zielke et al., 2009]. Based upon this framework, a serious game was developed that lets players increase their cultural expertise in simulated Afghan rural and urban environment. The 3D ADAT model provides a possibility to learn culture in a safe and realistic 3D environment. A very similar approach is presented by Sagae et al. [Sagae et al., 2010]. The authors designed five interactive arcade games training courses that conduct basic training in foreign language and culture. An estimated twenty-five thousand US military users have trained with the system so far. They claim, that although the concept was originally developed under military funding, the approach can be applied quite generally to language and culture learning.

5.3 Prototypes and Demonstrators

Going more into detail, we will now have a look at visualizations and virtual reconstructions of ancient historical sites. The idea of using 3D virtual worlds for cultural heritage education is not new. Many of the presented projects, however have never been released to the wide public and have exclusively been used for academic studies. In the following Section, we will present the most significant ones.

In 2005 Jacobson and Holden presented a realistic 3D model of an ancient temple for educational use to understand ancient Egyptian culture. *The Virtual Egyptian Temple* project [Jacobson and Holden, 2005] embodies all of the key features of a typical New Kingdom period Egyptian temple in a manner that an untrained audience can understand. The virtual world contains instances of a "High Priest", a pedagogical agent. The goal is to explore the model and gather enough information to answer the questions asked by the priest. The project is based on the *Unreal Engine 2*. Christopoulos et al. describe a more recent approach of a virtual reality exhibit implemented for the museum of Thermopylae located at the site of the original battle [Christopoulos et al., 2011]. The authors used storytelling techniques and principles of modern video games to disseminate historical knowledge about the battle and the associated legends. The project uses CGI movies and an interactive game (C++ and OpenGL) to create an immersive museum experience teaching ancient history. De Amicis et al. present the evolution across history of the town of Trento [De Amicis et al., 2008]. Users can navigate the territory across space and time and interact with the system to explore a very large set of documents and information that help them understand how the city has evolved. The project has been regarded as an essential didactical tool. Another approach to revive history is presented by [Frischer, 2008]. The Rome Reborn project is world's largest digitization project and has been running for 15 years. The aim of the project is to produce a high resolution version of Rome at 320AD. A lower res-

olution model was created for Google Earth[4], and finally the collaborative mode of the model for use with virtual world applications and aimed primarily at education [Frischer, 2008]. This project aims to develop a researchers' toolkit for allowing archaeologists to test past and current hypotheses surrounding architecture, crowd behavior, social interactions, topography and urban planning and development, using Virtual Rome as a test-bed for reconstruction. Maim et al. describe a very similar approach [Maïm et al., 2007]. For the *Ancient Pompeii* project, a model of ancient Pompeii was constructed and subsequently populated with avatars in order to simulate life in Pompeii in real time. The main goal of this project was to simulate a crowd of virtual Romans exhibiting realistic behaviors in a reconstructed district of Pompeii. Debevc introduces the *Parthenon Project* [Debevec, 2005]. The project goals were to create a virtual version of the ancient Parthenon monument in Athens from 437BC and its separated sculptural elements so that they could be reunited in a virtual representation. Within a short computer animation the author "visually reunites the Parthenon and its sculptural decorations" [Debevec, 2005]. A more game-like approach is shown within the *The Ancient Olympic Games: The Foundation of the Hellenic World* project by Gaitatzes et al. [Gaitatzes et al., 2004]. Its mission is the preservation and dissemination of Hellenic history and tradition. The authors have produced a number of gaming applications associated with the Olympic Games in ancient Greece, for example the "Olympic Pottery Puzzle", the "Feidias Workshop", or the "Walk through Ancient Olympia", where the user, apart from visiting the historical site, learns about the ancient games themselves by interacting with athletes in the ancient game of pentathlon. The visitors can wonder around and visit the buildings and learn their history and their function. As a last game-like example in this Section, we want to mention the *Virtual Priory Undercroft*. Located in the heart of Coventry, UK, the current site is not easily accessible for the public. Virtual Priory Undercroft offers a virtual exploration of the site in both online and offline configurations. Furthermore, a first version of a serious game has been developed at Coventry University. The motivation is to raise the interest of children in the museum, as well as cultural heritage in general. The aim of the game is to solve a puzzle by collecting medieval objects that used to be located in and around the Priory Undercroft. Each time a new object is found, the user is prompted to answer a question related to the history of the site[5].

5.4 Museum Games

Games that deal with cultural heritage are a modern phenomenon and often appear in the form of museum games, namely games that are integrated into an existing exhibition. According to [Eliëns et al., 2007] contemporary art is an intrinsic part of our cultural heritage and is, in comparison with more traditional art forms, far more difficult to present to a general audience. Museum games are a widely discussed object of research nowadays and provide an important basis for the work, as presented in this thesis. For this reason, we provide a brief (and as such necessarily incomplete) review of on-site museum games, virtual museums and social networking museum games.

[4] `http://earth.google.com/rome/`, last accessed: March 5, 2012

[5] Further information can be found under `http://wwwm.coventry.ac.uk/researchnet/iwarg/Pages/Projects.aspx`

On-site Museum Games

We will start with projects that include the usage of any types of games into the museum experience. These games are played on-site and are linked to a physical museum (or exhibition). To get a glimpse of the different types of gaming applications, Damala made the following classification [Damala, 2009]: multimedia games for museum handheld devices can be differentiated between solitary games or team games, communication among teams or team members may be synchronous or asynchronous. Games can be played outdoors, indoors (at a museum) or in a combination of both. Games can also take place in a variety of computer environments: 2D environments, 3D environments, augmented reality environments or combinations of the above. The authors differentiated between "treasure hunts" and observation games or mystery/detective games, in which the players have to solve a mystery case regarding one or several museum objects. Finally it should be noted that additional activities are sometimes also proposed for the pre- and post- visit phases. On-site museum games should also take different behavioral patterns of museum visitors into account. Research on this topic, however, is only in its infancy [Antoniou and Lepouras, 2010]. Concerning the design process of museum games, Schroyen et al. presented a mobile guide framework to support social-constructivist mobile guides and games [Schroyen et al., 2008]. The evaluation of the prototypes showed that mobile games that enhance the social relationships between visitors are an ideal tool to stimulate and motivate youngsters to visit a museum. The *ARCHIE* museum game is mentioned by the authors and considers social interaction and collaboration between pupils as the basic principle of the museum experience. Instead of aiming for a tool that offers the entire museum content to the visitor - be it by means of an adaptive system or not - they focus on conveying the key messages of the museum content through interaction. One good example for motivating youngsters to visit a museum is the game *Mystery at the Museum* (M@M). Klopfer et al. present the interactive learning game that was designed for synchronous play of groups over a two or three-hour period [Klopfer et al., 2005]. The primary design goals were to engage visitors more deeply in the Boston Museum of Science, engage visitors more broadly across museum exhibits, and encourage collaboration between visitors. The players in M@M cooperate as a team of experts to solve a crime, apprehend the criminals, and identify and retrieve the stolen artifact. Equipped with a Pocket PC and a walkie-talkie, players have many different ways in which they can collect clues - including interviewing virtual characters, collecting virtual clues found in exhibit halls, analyzing samples using virtual instruments, and understanding information from exhibits throughout the museum. The Pocket PC uses Wi-Fi positioning to determine the room in the museum. Wakkary et al. developed the PDA-based museum guide system *Kurio* that is also aimed at supporting families visiting a local history museum [Wakkary et al., 2009]. Similar to Mystery at the Museum, the authors developed a challenging game that fosters interaction with the museum's exhibits. In the game, families play time travelers stranded in present time because of a broken time map for their time machine. Each challenge asks family members to find historical information from within the museum. Challenges are assigned to each family member concurrently, allowing them to work collaboratively or independently. The interactive museum guide itself is comprised of a tangible user interface that is distributed over several independent (toy-like) tangibles (using RFID), a table-top display, and a PDA.

Ghiani et al. developed the mobile museum guide *UbiCicero* [Ghiani et al., 2009]. The main

motivation for the authors was to overcome the drawbacks of using passive RFID tags that forced the users to stand in very close proximity to the artworks, which is not realistic in museum environments. They propose a multi-device, location-aware guide supporting museum visits, which also provides the possibility of enriching the museum visits through individual or collaborative games. Its main contribution is in the ability to exploit multi-device environments, in which users can freely move around with their mobile guide but also exploit large screens connected to stationary PCs when they are nearby. The multi-device guide system was implemented for the Marble Museum of Carrara and the Natural History Museum of Calci. Both the access to museum information and the associated games can benefit from the availability of multiple devices. A different technology is used by Ceipidor et al., who make use of QR-Codes and mobile phones to allow interaction with the artifacts at the Norsk Telemuseum, Norway [Ceipidor et al., 2009]. The authors present a mobile museum game addressed to 11 to 14 year-old students . The players have to search and photograph artifacts to solve a sequence of riddles. The letters of a secret word are orderly provided on right answers, spurring the interest for the exhibition through the mobile phone. A preliminary field test in the Norsk Telemuseum gave very good results. In an one year lasting project at the University of Applied Sciences in Bremerhaven, Jenner and Araújo developed a digital learning game for the German Maritime Museum in Bremerhaven [Jenner and Araújo, 2009]. It is targeted to school pupils in the age between 10 and 14 and should explain the importance of the cog for trading activities between Hanse cities in the 14th century. Instead of using mobile devices, the key-interest was the design and building of an easy-to-use and attractive stationary computer terminal in the museum, including a special control-interface. The resulting game was evaluated in an user-test with 29 school pupils. It showed that the game makes fun and is easy to understand. Another game-like approach to deal with cultural heritage is proposed by Neto et al. The authors developed a game called Solis' Curse that was used as a way of testing the knowledge acquired during the museum visit [Neto et al., 2011]. The main purpose for this game is to improve cultural heritage awareness, which occurred when the visitors re-examined the exhibition to get a better score in the game. Solis' Curse depicts a realistic 3D model of the Pantheon, divided in five different levels. Each level represents a different question, and answering it correctly will get the player through to the next level, revealing a new piece of the model. The game was presented on the exhibition using a kiosk concealing a computer with a touch screen and a microphone and speakers system. A good example for an outdoor museum game is VeGame [Bellotti et al., 2003], a handheld platform and educational software to make exploring cultural heritage in Venice a challenging and compelling experience. The VeGame project explores how mobile gaming can help users enhance their experience of art and history through a pleasant and challenging interaction with the heritage and people in an urban environment. VeGame's participants form teams and play along Venice's narrow streets, discovering the city's art and history.

Virtual Museums

The projects presented so far are a part of a real word museum or exhibition site. Now we will deal with projects that can be seen as self-contained museums and that do not share a physical pendant. Many of these virtual museums appeared in Second Life, a social virtual world that was pushed by a huge media hype in 2007. The users started to build museums that would have

been impossible or incredibly expensive to accomplish in the real world. And that is exactly why they still are of great interest. Zhu and Xiang highlight the advantages of virtual museums (in Second Life) [Zhu et al., 2007]: they raise the sense of sharing among groups, they offer an environment that enhances sharing through interoperability and they provide the power to create interactive learning experiences that would be hard to duplicate in real life. Also Livingstone and Kemp see these platforms as powerful environments for teaching and learning [Livingstone and Kemp, 2008].

One example for a self-contained "museum" is presented by Fominykh et al. The project deals with contemporary cultural heritage and presents the *3D Virtual Environment for Learning Arts* (VELA) [Fominykh et al., 2008]. VELA is a 3D environment where users, represented by 3D avatars, can learn art by traveling through European cities, visiting art exhibitions, galleries, artists' studios and interact with agents/bots to get information. Scenes of VELA resemble real cities with corresponding elements (houses, streets) and interiors though without direct correspondence to their physical counterparts. This provides an atmosphere of real presence, easily recognizable by users. There are several interactive tests and quizzes in VELA that can be used to control learners' knowledge about the subject.

VELA, and many other projects such as Travel in Europe [Bellotti et al., 2008b] and Second China [Fishwick et al., 2008, Henderson et al., 2008], do not offer the possibility to personalize the content shown within the virtual museum. According to Yessad et al., an important problem of serious games is the difficulty for instructors to adapt the storyboard, the scripts and the game levels of the video game to new pedagogical objectives once the game development is achieved [Yessad et al., 2010]. To counteract this, Mateevitsi et al. developed an authoring system to facilitate virtual museum development and usage [Mateevitsi et al., 2008]. The system is based on the Torque game engine, ensuring thus minimal cost and good performance, and includes provisions that enable museum curators to design the virtual museum without any specialized knowledge and thus removing any need for programming. Besides visual and auditory information, museum curators may also provide metadata, which provide additional information to the visitor, while they can be also exploited for searching for exhibits with certain properties. A guide is also included in the museum to present additional information to the visitors and aid them throughout their tour.

Social Networking Games

Most recent projects deal with museum games that are directly integrated into modern social networking platforms. According to Goins, those games fit into the constructivist concept of learning by actively engaging the participant in the learning process [Goins, 2010]. The same author developed the Facebook game *MyMuseum*. MyMuseum is a resource management game that allows large numbers of players to experience and learn about museum objects. Players are able to create their own gallery space by buying furniture and digitized objects from the Smithsonian Museum of American Arts collection. In order to make more sophisticated collections, the player has to adapt his choice of exhibits to artists, style, history and style. The prototype is currently under development at the Rochester Institute of Technology, in conjunction with the Luce Foundation Center for American Art at the Smithsonian American Art Museum.

The goal of the project presented by Koushik et al. was to design an integrated system for the California Academy of Sciences that combined new technology with a social-networking based website to promote educational learning [Koushik et al., 2010]. The museum visitors start by creating profiles on the California Academy of Sciences website. Initially they are able to personalize a limited number of characteristics of their avatars. Once they visit the museum, they play mini-games on iPad kiosks to accumulate points on their accounts. These points can then be redeemed at home by returning to the California Academy of Sciences website. Accessing the website from home allows the user to further personalize an avatar, learn more facts, and compare their scores on the mini-games and their avatar with those of their peers. Points can be redeemed to upgrade the avatar's available attributes and uniforms. The use of new technology drew in users that would not have otherwise engaged in the experience. Another recent example is the Facebook game *Nachts im KHM* ("Night at the KHM") about the Museum of Art History in Vienna, Austria. The player uses a virtual flashlight to illuminate painting details. It is possible to challenge friends, share scores and earn achievements (such as "You played three days in a row"). The museum rewards the best players with free tickets and special guided tours.

An important type of games that are dependent on a vivid online community to work successfully, are so called *crowdsourcing games*. Crowdsourcing, in general, means to outsource tasks to an undefined, large group of people or community. Museums can make use of crowdsourcing to enhance their collections online without committing intensive curatorial resources. According to Ridge, these crowdsourcing games, or *Museum Metadata Games* (MMG), are designed to help improve the mass of "difficult - technical, near-duplicate, poorly catalogued or scantily digitized - records that make up the majority of many history museum collections" [Ridge, 2011]. The authors produced two games based on the mass of registered collections of science and social history museums: *Dora* is a tagging game that lets the player assign tags to different artworks in a hands-on way. The second game *Donald* introduces a more complex game scenario and asks the player to search for additional information and links related to an artifact on the web. Both games help the museum to collect metadata for their collection at no (or very low) cost.

5.5 Commercial Historical Games

Commercial games are sometimes placed in a historical setting and thus obtain the status of a game with learning purpose. For example, the *Playing History* game series[6] is about experiencing personal stories in the larger world history. The series places the player in historically significant and interesting time periods, where she will get the chance to be part of history in the making. The idea behind Playing History is to let players experience the small story in the larger history. The games (e.g. *The Plague*, dealing with 14th century Florence and black death, or *Slave Trade*, which is about the 18th century and experience the horrors of the transatlantic slave trade) offer a relevant story, which presents central parts of the time period to the players. Because the players collect information and build knowledge as a part of the story, learning occurs naturally as they play and users make their own decisions to influence the story.

[6] `http://www.playinghistory.eu`, last accessed: Feb 29, 2012

A highly successful example for a commercial historical games is *Great Battle of Rome* (Slitherine Strategies 2007). The game mixes interactive 3D real-time tactical simulation of actual battles with documentary information. Similar to this and perhaps the most successful representatives of this type of historical games are from Creative Assembly's *Total War* series, which provide a gameplay combination of turn-based strategy (for global events) and real-time tactics (for battles). Here, a historical setting is enriched with information about important events and developments that occurred during the timeframe experienced by the player. While the free-form campaigns allow the game's players to change the course of history, the games also include several independent battle-scenarios with historical background information that depict real events and allow players to partake in moments of historical significance. The use of up-to-date games technology for rendering, as well as the use of highly detailed game assets that are reasonably true to the historical context, enables a fairly realistic depiction of history. The latest title in the series, Empire Total War (released in March 2009), depicting events from the start of the 18th century to the middle of the 19th century, *Napoleon: Total War* (2010), depicting European History during the Napoleonic Wars, and *Shogun 2: Total War* (2011), placed in a Japanese setting, makes use of some of the latest developments in computer games technology.

CHAPTER 6

ICURA - The Immersive Cultural Training

"Games put culture "at play", not just reflecting culture"
(Salen and Zimmerman, 2003)

Virtual worlds have the power to expand the knowledge of a foreign culture by presenting the information in a visual context. When we have a look at recent projects dealing with cultural heritage, in particular with cultural diversity, we can see that many of them were developed for a military purpose only (such as *Tactical Iraqi* and *Virtual Iraq* [Zielke et al., 2009]) and were not published to the wide public. Others, however, like the *Second China* project [Henderson et al., 2008], do not incorporate game-like elements to raise the player's motivation. In order to fill this gap, we developed **ICURA** (The **I**mmersive **Cu**ltural T**ra**ining), a serious game that provides the opportunity to learn more about a specific culture. As thematic framework we chose to teach facts about contemporary Japanese culture, because it's cultural uniqueness provides a rich source of interesting content (see Figure 6.1 for a first impression). As an extension to the e-Tourism environment *Itchy Feet*, ICURA can be seen as a practical guide to living in Japan that should appeal to teenagers and adults as well. The main goal is to combine aspects of learning and fun in an immersive 3D environment to make the communication of knowledge an entertaining experience. In Section 6.3 we present the results of the evaluation of a user study with 20 participants. The comparison of pre- and post-test results describe the learning effect of ICURA. At the relevant passages we will refer to game design and digital game-based learning theories (from Chapter 3 and 4) and how they have influenced our design decisions. ICURA is the first of two practical artifacts designed for this PhD thesis and was developed between March 2010 and April 2011. The game exclusively deals with attributes of intangible cultural heritage, including languages, traditions and behavioral rules. Tangible attributes of cultural heritage will be the central issue for the second artifact, ThIATRO (see Chapter 7).

Figure 6.1: The entry gate to the fictive town of *Kuya*. Upper left corner: Information Agent, lower area: Inventory

6.1 A Quick Look at ICURA

Over the last years many topics have been covered within serious games, ranging from simple learning games to highly elaborate training simulations for military purposes. Here we want to focus on the opportunities serious games provide in the field of cultural awareness and cultural heritage. The term *culture* is usually associated with "a life-world as well as a set of behavioral rules, forms of thinking and norms that emerges from human group interaction" [Fishwick et al., 2008]. Cross cultural interaction is a very important matter that implies the detailed understanding of the target culture. Behaving in an inappropriate way within a foreign culture can lead to embarrassing moments, and moreover, can cause unintentional disrespectfulness. There are many webpages describing and explaining cultural habits and regional distinctions of different travel destinations. Let us assume, we are planning a trip to Japan: Japanese people are known for being friendly and polite to foreigners. They set a high value on their culture and expect every tourist to adjust to their behavioral patterns. Serious games represent a "safe" way to make mistakes and to learn culture in an environment as realistically as possible [Zielke et al., 2009]. Video games create, what the psychologist Eric Erickson has called, a *psychosocial moratorium* - that is, a learning space in which the learner can take risks where real-world consequences are lowered [Gee, 2003]. For this reason we decided to design the serious game ICURA that confronts the player with contemporary Japanese culture and etiquette in a safe environment. It can be used as a tool to gather information about Japanese culture in a playful way, either for

pre-trip planning or for raising one's understanding for foreign cultures in general.

One may argue that those basic cultural facts can be simply looked up in books or on the Internet within a much shorter time, without the usage of a (maybe) technically demanding 3D game. As we have seen in Chapter 4.4, the skeptic often equates leaning with the ability to reproduce a certain set of facts on a given amount of time. This *rote memorization* is learning of short duration and little relevance to solving real problems. One major goal of ICURA is to provide learning content that goes beyond basic tourism information. The game confronts the player with tasks relevant to real-world problems. By this means, we aim to create knowledge that may possibly be remembered and put into practice even years after playing. Additionally, the issue is not starting players with easy cases. The issue is starting them with cases that are basic or fundamental in the sense that they lead the learner to discover and practice what are, in fact, fruitful patterns and generalizations. Fruitful patterns and generalizations, according to Gee, are ones that allow the learner to make real progress in the domain and that can serve as the correct basis of good guides for more complicated patterns and generalizations that need to be discovered later by confronting more complex and less-basic situations and cases [Gee, 2003].

3D Learning Environments

Using 3D environments for the communication of knowledge within a computer game is a design decision that has to be carefully considered. 3D adds a range of difficulties: first of all, it is more challenging to control within 3D space. Untrained users need to pay attention to the navigation and this could result in losing one's focus in the learning content. Poor screen resolutions and higher hardware requirements (in comparison to 2D) additionally argue against the usage of 3D. Despite these known issues, we came across some major advantages of 3D that have been decisive for our design steps. Hedberg et al. emphasize the ability of virtual environments to situate the learning within a meaningful context [Hedberg and Alexander, 1994, Dalgarno and Hedberg, 2001]. Because a 3D environment can provide a level of virtual realism and interactivity consistent with real-world, it is possible that ideas learned will be more readily recalled and applied within the corresponding real-world environment. This happens by the creation of situated tasks that are both meaningful and intrinsically motivating. As stated in Chapter 4.5, the player learns by probing the virtual world, which involves looking around, clicking and engaging in certain actions. An immersive 3D environment that includes exploration and discovery may incentivize the player to take these actions. Based on her reflections, the player forms hypotheses about her actions that, in succession, strengthen her knowledge. In addition it is to say that 3D environments (if visually appealingly designed) have the power to raise some initial interest and curiosity. However, Hedberg et al. also point out that this novelty effects wears off [Hedberg and Alexander, 1994, Dalgarno and Hedberg, 2001].

An e-Tourism Perspective

ICURA is an extension to the e-Tourism environment *Itchy Feet*. Itchy Feet is a game-like 3D e-Business application that aims at creating a lively society of travelers who exchange travel experiences, recommend tourism destinations or just listen to catch some interesting gossip. Moreover, business transactions such as booking a trip or getting assistance from travel advisors

or community members are constituent parts of this environment [Berger et al., 2007]. Details about Itchy Feet have been covered in Chapter 1.2 and can be looked up in Ingo Seidl's PhD thesis [Seidel, 2010]. As an additional eye-catcher and as entry point to ICURA, we placed a Japanese temple into the 3D World of Itchy Feet. As soon as the avatar enters the temple, the system offers the chance to play ICURA. When the game is finished or broken up, the avatar is teleported back to the initial position in Itchy Feet. Both packages, the Itchy Feet environment and the ICURA application, can be downloaded from our project's website `www.itchy-feet.org`.

6.2 ICURA - A Detailed Description

Walkthrough Scenario

Once the user has started ICURA, she finds herself in a game-like 3D environment. She is prompted to complete a test that consists of twelve singe-choice/multiple-choice questions concerning language basics, cultural specificities and Japanese etiquette. This test is a measure to determine the preliminary knowledge of the player and subsequently serves as a basis for analyzing the learning effect of the game. Three different screens introduce the player into the user interface and the controls, as well as the purpose and the plot of the game: The player slips into the role of an Austrian tourist in Japan, who wants to learn more about Japanese culture, habits and some language basics. The plot of the game suggests that the player is a member of the Couchsurfing Network[1] who has arranged a meeting with another member in the fictive town of *Kuya* to stay at his place for some time. Unfortunately, both forgot to communicate the exact address or meeting point. All the player has is a print-out of the host's Couchsurfing profile and a copy of previous emails. In this emails, Shoji (our host) describes typical rules of behavior for tourists in Japan. So, the main goal of the game is to find Shoji. Various subgoals are added during the progress of the game (for example, to find a present for Shoji). So, to complete the game, the player has to investigate the 3D environment, collect items, combine them and talk to persons. As soon as the player reaches the end of the game and thus having found her host, she is faced with the test again. The game calculates the results and visualizes them in form of two progress bars (see Figure 6.2).

The final score is composed of the number of correct answers in the post-test and the duration to complete the game. A correct single-choice question adds 20 Points to the final score, a correct multiple-choice question brings 40 points. The faster the game is completed, the more bonus points the player gets. If it takes the player longer than 30 minutes to complete the game, no additional points are assigned. For example, someone who completes the game in 22 minutes and answers all the questions correctly, receives 720 points. The results are then uploaded to a server and displayed on an online scoreboard. The highscore is stored in an SQL database, together with the nickname, number of correct answers on the pre-test, number of correct answers on the post-test, the final score and a timestamp (ordered by score, descending). The nickname is requested at the end of the pre-test. As soon as the player finishes the post-test, the results are sent to the server and displayed online. A link to the scoreboard is also integrated

[1] `http://www.couchsurfing.org`, last accessed: May 2, 2012

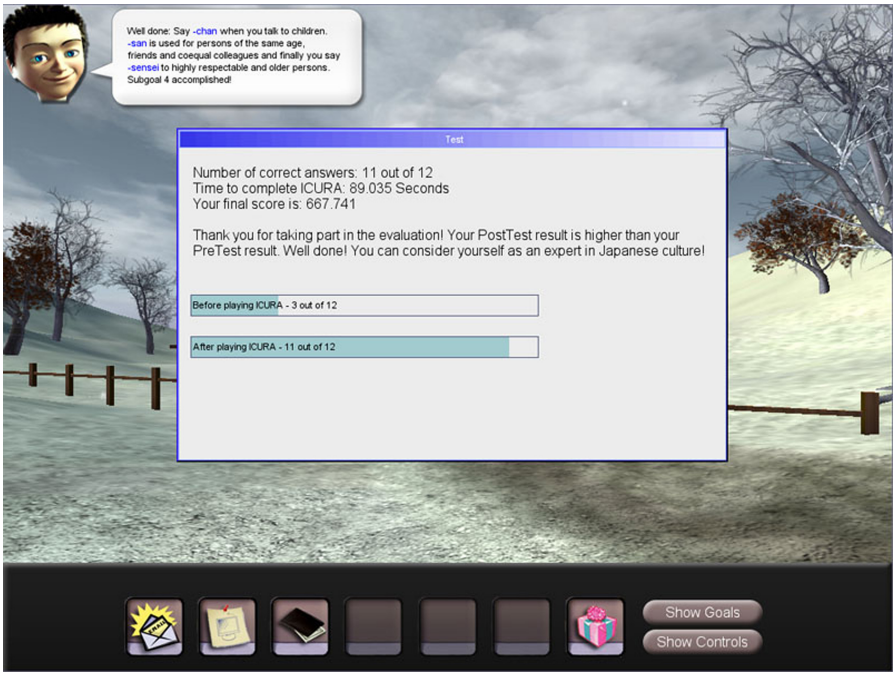


Figure 6.2: Final score and the results of the pre- and post-test

in the Itchy Feet public site[2]. The game also includes a function to display the wrong answers from the post-test and thus provide the opportunity for the learners to reflect on the knowledge they have learned. [Sheng et al., 2007] calls this the "reflection principle".

Technical Background

Torque Game Engine

Anderson et al. describe game engines as "a set of reusable components that can be transferred between different games" and as "glue layer that connects its component parts" [Anderson et al., 2010]. Choosing the right game engine for our project was an essential design decision.

In general, three types of game engines can be differentiated: commercial engines, open source game engines, and modifications (mods). Commercially developed game engines are usually expensive, and while there are affordable solutions, these generally provide fewer features, thus potentially limiting their usefulness [Anderson et al., 2010]. Furthermore, there exist open source game engines, such as *Quake Engine* (id Software), which are either commercially developed or close to commercial quality, making them a viable platform for the development of virtual worlds, although they may lack content creation tools. Finally, there is the possibility of taking an existing game and modifying it for own purposes, which many recent games allow users to do. The only requirement is the purchase of a copy of the relevant game, combined with

[2] `http://www.itchy-feet.org/displayscores.php`, last accessed: May 2, 2012

access to high-spec modern game engines, as well as the content development tools that they contain. Anderson et al. state *The History Game Canada* [3] as an example for using *Civilization III* for cultural heritage issues [Anderson et al., 2010].

ICURA was developed with Torque Game Engine Advanced (TGEA) 1.7 (and later 1.8), an commercially (but affordable) open source game engine developed by *GarageGames*[4]. We favored Torque over other open source engines because its support for indoor/outdoor rendering, animation, a lighting engine, powerful editors and an easy-to-learn scripting language. Furthermore, by the time of planning ICURA, the whole code-basis of Itchy Feet was already grounded on the Torque engine. And it was one goal of the project to seamlessly connect both worlds within one consistent framework. Torque is an industry-proven game engine and has been used in numerous commercial and independent games. In the scientific world it has been utilized for research projects as well (see for example Mateevitsi et al. [Mateevitsi et al., 2008] in Section 5.4). Moreover, the engine is widely used in education for teaching the principles of 3D game engines. The GarageGames website lists more than 200 schools and universities that use the Torque game engine in their class rooms.

A major advantage of Torque is the royalty free licensing model that allows developers to distribute and publish their games without further costs. In addition, the developer provide several editors and tools for the creation of games and 3D Virtual Worlds. These editors include a *World Editor*, used to arrange objects in the 3D virtual world, a *Terrain Editor*, used for the creation of the terrain, and an *Graphical User Interface (GUI) Editor*, used for the design of the heads-up-display and 2D interface elements. The perhaps most useful tool was the *Torque Constructor*, a Constructive Solid Geometry (CSG) WYSIWYG brush editor that was used to model the 3D objects, first for Itchy Feet, and later for ICURA. It supports numerous industry-standard CSG model (.map) formats, as well as a seamless export function to Torque Game Engine. We favored this light weight modeling tool over commercial solutions (such as *Maya* or *3ds Max*), because its surprisingly steep learning curve and its direct integration to Torque projects. Figure 6.3 shows the main buildings of ICURA: a tea house, a shop, a Japanese temple and Shoji's house (the end point of the game). Figure 6.4 shows the wireframe model of the tea house in Torque Constructor. However, the Torque Constructor only supports modeling convex objects. This is because all of the collision in Torque is done against closed convex collision meshes. For concave models (like the temple's roof in Figure 6.3) and for models that needed some transparency effect (like the walls of the tea house) we used 3ds Max and a plugin for Torque support.

The behavior of objects and the game logic itself was programmed via the scripting language *Torque Script* - using the development environment *Torsion*. If the scripting language is not applicable (due to functional or speed limitations), it is possible to alter the game engine itself. The code is written in C++ and is directly compiled into the game engine executable.

[3] `http://historycanadagame.com`, last accessed: May 2, 2012

[4] `http://www.garagegames.com/`, last accessed: May 2, 2012

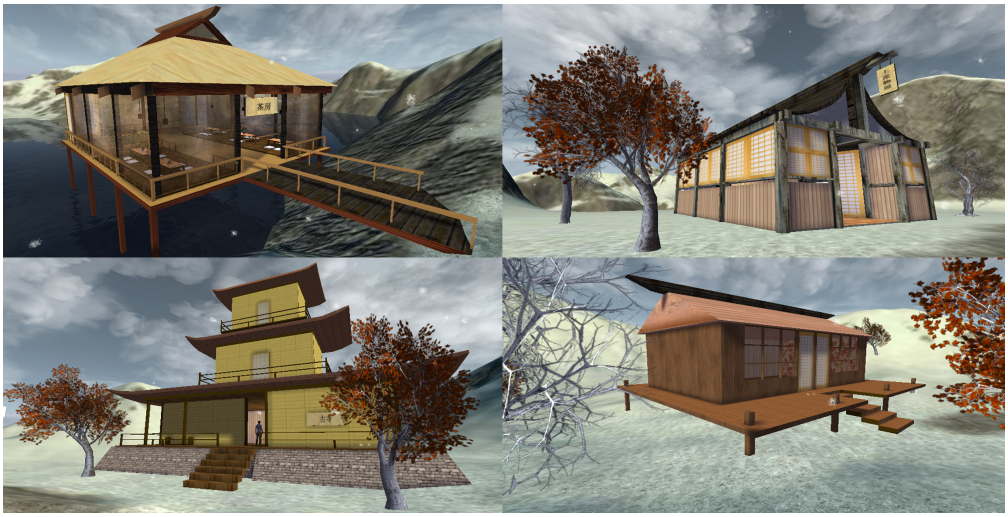


Figure 6.3: The main buildings of ICURA, top left: tea house, top right: shop, bottom left: temple, bottom right: Shoji's house

3D Landscape

In addition, we decided to use the external tool *L3DT*[5] to create the landscapes for our 3D worlds. Although Torque provides a tool to sculpt landscapes, this solution turned out to be visually unattractive and extremely hardware demanding, because the whole calculation process is carried out by the central processing unit (CPU). An alternative was provided by L3DT, an application for generating artificial terrain maps and textures. It is primarily intended for game developers seeking to make large high-quality 3D worlds, as well as for digital artists who would like to have full control over their creations. L3DT also comes with a plug-in that allows end-users to directly export their creations to Torque. For ICURA, we created shadow maps, normal maps, huge textures and the related height fields with L3DT. The result was a 3D landscape with the size of 800 to 800 meters. The outside area was filled with a skybox composed of six .jpeg images showing photos of Kyoto's skyline. At some points the textures and height fields were modified manually to create a walkway that provides some guidance for the player and to flatten the surface for positioning the buildings. See Figure 6.5 for a screenshot of this texture-map. Within Torque, these terrains (called "Atlas terrains") are calculated by the graphics processing unit (GPU), providing some noticeable performance boost. However, by the time of implementation the usage of Atlas terrains was not supported by Apple's graphic drivers and thus ICURA was released for Windows only.

Additional Components

In order to further immerse the player into the game and to raise the feeling of "being there", we integrated sound, particle effects, precipitation and a dialogue system (see also [Houtkamp

[5] `http://www.bundysoft.com/L3DT/`, last accessed: May 2, 2012

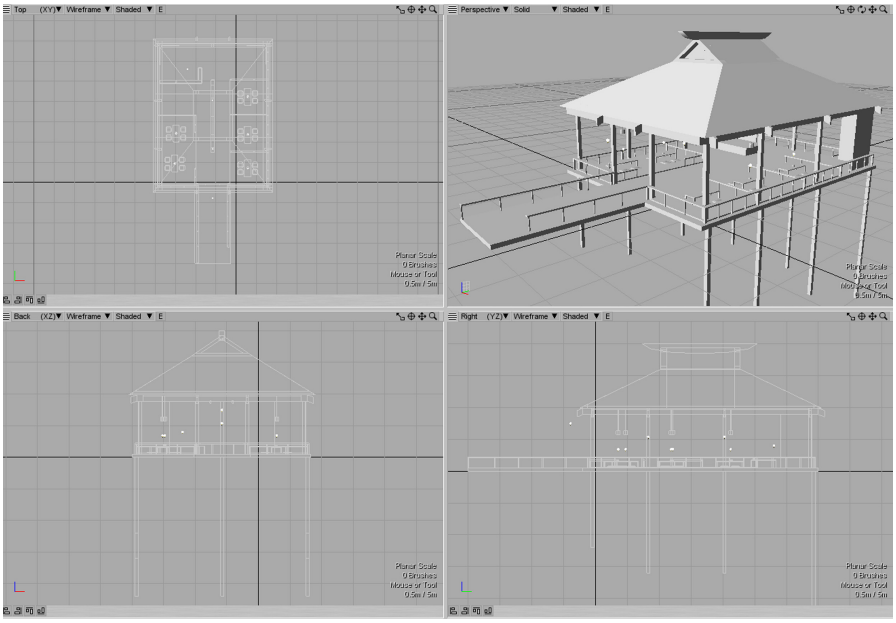


Figure 6.4: Wireframe model of the Japanese tea house in Torque Constructor

et al., 2008] and [Carron et al., 2009]). Sound effects were taken from *freesound*[6], a collaborative database of creative-commons licensed sound samples. Among others, we used sound effects to draw the player's attention to new information given by the Information Agent (see next Section) and as auditive feedback to user interface inputs. In addition, we placed 3D sounds for wind at different spots on the landscape and the sound of a boiling tea kettle that acts as a hint for one of the game's puzzles. This teakettle was also provided with a particle effect to underline it's importance for progressing the game. Torque also provides means to create "precipitation effects". The term precipitation describes weather effects like snow, sandstorms or rain in Torque. We added some falling snowflakes to the 3D winter world and adjusted the precipitation parameters to give it a natural look. To create some more diversion, we added an animated cloud layer that is defined by varying parameters for `CloudHeight` and `CloudSpeed`. Another important component we integrated in ICURA was the so called "YackPack" that provides the code basis for adding dynamic conversations between players and NPCs to the games. The dialogue system lets the player interactively choose what to say and which answers to give. All the conversations are stored in text files that can be easily modified. See Figure 6.6 for a screenshot of a dialogue with a NPC.

Controls and User Interface

The avatar is controlled from a first-person view by using the cursor or the WASD keys. Mouse-look functionality is provided by mouse movement that can be toggled with the tab key. To

[6] `http://www.freesound.org/`, last accessed: May 2, 2012

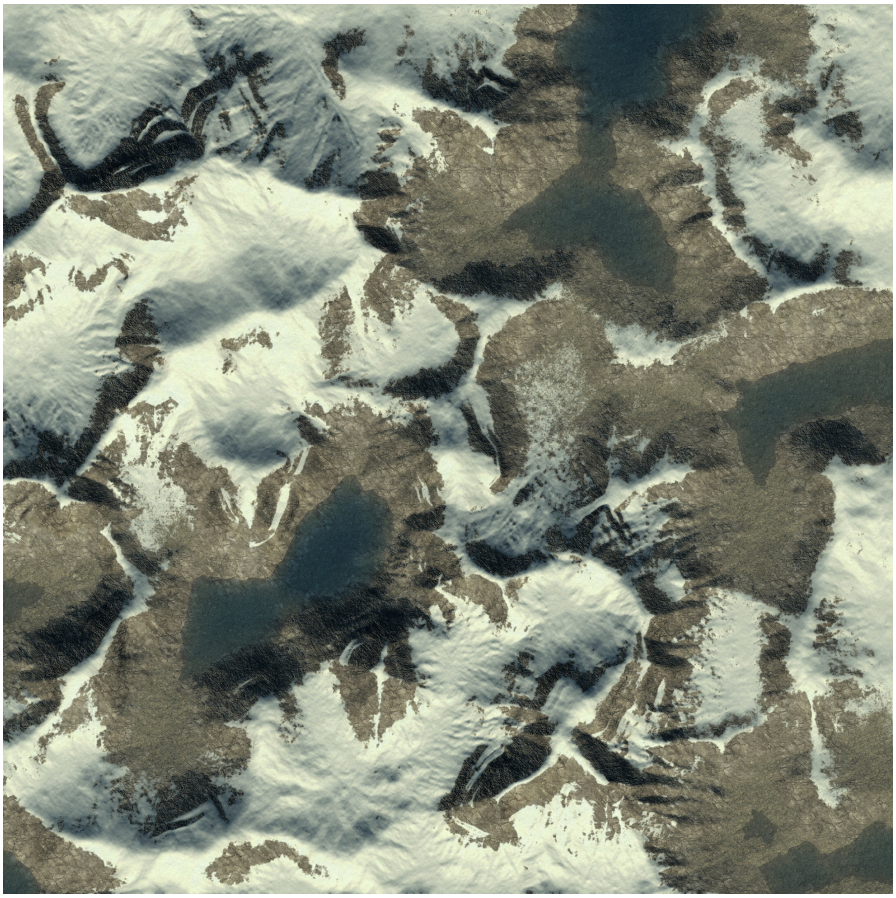


Figure 6.5: The texture map for ICURA's 3D environment, calculated with *L3DT*

interact with the 3D environment, the mouse cursor is placed over an object. A change of the cursor's shape indicates the possibility for an interaction. By left clicking an object, the player investigates an object, a right click triggers some kind of interaction, such as taking an object or talking to a NPC.

Concerning the user interface design, our goal was to keep it as simple as possible. Mark Prensky says that "the key is to have an interface that, while complex in its full capabilities, is easy to learn as you go along, letting you control only the basic things at the beginning, and assumes more and more control as you go" [Prensky, 2001a]. ICURA follows the example of classic 2D adventure games from the early 90's and incorporates a simple GUI that includes an inventory and some buttons. The inventory stores all the objects we carry with us, for instance our host's Couchsurfing profile. A soon as we take an object in the 3D World, it appears as a 2D replica in our inventory. In addition, the inventory allows us to investigate the stored items and to combine them with each other. A right click on an inventory object triggers a small text box to appear showing the words "Right click object to use `selectedObject` with". Two buttons allow the player to display a summary of the controls of the game and the goals

Figure 6.6: The dialogue system of ICURA

and subgoals the player has to accomplish. Completed tasks are marked with a green check, a red cross signifies an open task. The upper left corner shows a small text box, the so called *Information Agent*. It documents the progress of the game and provides the player with useful information about Japanese culture and etiquette. Each important action we take is accompanied by a new message that is crucial for the learning process. Figure 6.1 on page 56 shows all the GUI elements. Every time the game holds some new pieces of information ready, the speech bubble blinks red and a discreet alert sound is played. As first test runs showed, this approach successfully calls the player's attention to the learning content.

Design Process

It took about 13 months to finish ICURA, starting from the first idea until the game reached a level that was ready for evaluation. After agreeing on the thematic framework, we started to think about genre choices, core mechanics and rules.

According to Prensky, the type of game you finally choose will determine the level of engagement [Prensky, 2001a]. He proposes a comparison of learning content, activities and their corresponding game style. ICURA mostly deals with learning content in the areas of "judgement", "behavior", "observation" and "language". This content leads to the following learning activities: "choice-making", "feedback", "immersion" and "observation". For all these activities, Prensky proposes adventures and role-playing games. In consideration of the limited time range of the project, the idea of making a role-playing game seemed technically too demanding.

So, based on Prensky's recommendations, we decided to present the learning content in form of an adventure game. We continued thinking about the core mechanics of the game. Salen and Zimmerman define core mechanics as "the essential play activity players perform again and again in a game" [Salen and Zimmerman, 2003]. It is essential to clearly define the core mechanics early in the design process, because later changes are incident to great expenses. The core mechanics of ICURA can be summarized as follows:

- Probing the virtual world by means of *looking around* (mouse movement), *clicking* on objects (mouse buttons) and *moving* (cursor or WASD keys)
- Engaging in certain actions: talking to NPCs, collection objects, combining objects in the inventory, and use the objects to trigger certain events.

The rules of ICURA are defined by the characteristics of the 3D world. The player acts within an area of 800 x 800 meters. There is no "game-over" situation. Whenever the player finds herself in a dead-end situation, the inventory object *Shoji's Email* acts as hidden help function that provides hints to some of the main puzzles. We took great effort to provide the player with meaningful tasks and feedback during the course of the game. For this reason, we created an "Action List". This list describes all the objects, NPCs and inventory items in the game and their response to mouse inputs. For example, a left click on the object *napkin* in the 3D Virtual World generates the words "Some clean white napkins" in the HUD, a right click brings on the words "I will take one of these" and adds the item to the inventory, accompanied by some auditive feedback. This clear definition of responses was created for every object in the game to avoid logical flaws. It was also important that these responses were meaningful to to the player and not just uninspired "I can't do that" messages. We tried to make sense of the objects and fitted them into the emerging plot and virtual world the player is discovering.

In a final step, we were checking the correctness of Japanese characters that appear in the game. For example, the Japanese language uses three different words for the term "tea house", depending on if it is a classical or modern one, or a coffee shop chain. A great help was provided by the WordReference.com forum[7] and its users, who checked the correct usage of the featured terms. The whole design process was supported by the project management and bug/issue tracking system *trac*[8] where all the open issues that had to be clarified before starting the evaluation of ICURA, were noted down.

Design Principles

Based on the work of [De Freitas and Jarvis, 2006] and the principles described in Chapter 3 and 4, ICURA incorporates different game design and learning principles to effectively communicate knowledge about Japanese culture and etiquette. This Section highlights five design principles that have been considered most important by us for making the game.

[7] `http://forum.wordreference.com/`, last accessed: May 2, 2012
[8] `http://trac.edgewall.org/`, last accessed: May 2, 2012

A Constructivist Perspective

Learning in 3D Worlds follows a constructivist perspective. Central to the constructivist theory is the belief that knowledge is constructed, not transmitted, and the learners play an active role in the learning progress. Johnson et al. state that a player form memories, make associations and use the context later to aid in recall [Johnson et al., 2007]. So, the creation of a concrete context is crucial for the learning success. To foster the construction of knowledge, learners should also have opportunities for exploration and manipulation within the learning environment. ICURA provides a huge game area that is freely accessible. The player has to explore this world and interact with the objects and persons to fulfill the given tasks. The overall plot is authentic and provides a concrete learning context that can be carried over to real life experiences. A learning game should always relate the material to the learner's experiences and organize the material into small chunks, building up from simple to complex. While implementing the game, we turned our attention to designing realistic and meaningful tasks. To follow the principles of constructivism, the puzzles and its solutions are an inherent part of the game plot. Every object, every action and dialogue has a meaning in the game. To make sense of them the player fits them into the emerging plot and the content will be remembered. As we have already said in Chapter 4, it is essential to "let the player experience a delicious moment of wonderfully embodied and situated meaning" [Gee, 2003]. To quote an example, in one scene the player has to gain access to a Japanese temple to fulfill a subgoal. In order to successfully achieve this task, the player has to put on the slippers, provided at the temple's entrance. Otherwise a temple guard refuses the entrance. So, the player has to deal with the learning content actively to fulfill the task and can apply this information to a situation in real-life. This approach not only increases the motivation but also compels the player to think about, organize and use information in ways that encourage active construction of meaning [Greitzer et al., 2007].

The Player's Motivation

It is a challenge to entice people to play for hours. [Greitzer et al., 2007] proposes five guidelines to keep the player's motivation. Leveling-up ("getting better" at something), adaptability of the game's difficulty, clear goals, interaction with other players, and a shared experience. We tried to incorporate as many guidelines as possible in ICURA. As described above, we integrated a button that lets the player display the goals and subgoals of the game. The specific goals are: find your Couchsurfing host, find a present for him, wrap up your present, gain access to the temple, and find out where your host lives. As soon as a goal is accomplished, it gets marked with a green check mark. So, the goals and the current status are available at every time in the game. ICURA is a single-player game, so in the first instance there is no interaction with other players. Due to the fact that ICURA is embedded in the 3D e-Tourism environment Itchy Feet, the interaction happens as soon as the game is finished. The avatars can discuss about the gaming experience and can exchange their views about the learning content. Two of the guidelines proposed by [Greitzer et al., 2007] are tasks for future work: the recent version does not allow to adapt the difficulty. The online highscore can be seen of some kind of leveling-up functionality, although it is not directly integrated into the game.

Usability

Pinelle et al. define usability as "the degree to which a player is able to learn, control, and understand a game" [Pinelle et al., 2008]. Failures in a game's user interface design can have a negative effect on the overall quality and success of a game and thus also influence the communication of learning content. Based on the analysis of video game reviews, Pinelle et al. developed ten usability heuristics to help avoid common usability problems. These are:

- Provide consistent responses to the user's actions.
- Allow users to customize video and audio settings, difficulty and game speed.
- Provide predictable and reasonable behavior for computer controlled units.
- Provide unobstructed views that are appropriate for the user's current actions.
- Allow users to skip non-playable and frequently repeated content.
- Provide intuitive and customizable input mappings.
- Provide controls that are easy to manage, and that have an appropriate level of sensitivity and responsiveness.
- Provide users with information on game status.
- Provide instructions, training, and help.
- Provide visual representations that are easy to interpret and that minimize the need for micromanagement

ICURA follows these heuristics and provides consistent response to the user's actions. The Information Agent in the upper left corner of the screen is a central design element. It comments every action, informs the player about her current status and provides instructions and help. As for the puzzle mentioned above, the Information Agent proposes to take a look into Shoji's email for a hint before entering the temple. The email tells the player to put on the slippers before entering the temple.

The Agent Principle

The idea of using a virtual tutor was already used in other projects. In *Tactical Iraqi* (see Section 5.1 "Related Work") it is depicted as a talking head that evaluates the learner's pronunciation and syntax [Losh, 2006]. In *Tactical Pashto* the player gets assistance from a non-player character that takes the form of an Afghan go-between [Johnson et al., 2007]. In this context, ICURA was strongly influenced by [Sheng et al., 2007] and the idea of a "story-based agent". Agents are characters that help in guiding learners through the learning process. These characters can be cartoon-like or real-life characters. The usage of an agent as part of story-based content enhances learning. In ICURA, the Information Agent looks at a learner's responses and tries to decide why he or she made an error and gives specific feedback. It guides the player through the

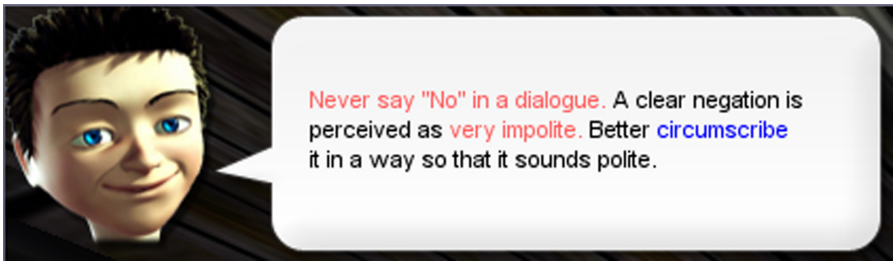


Figure 6.7: The Information Agent teaching Japanese etiquette

course of the game and simultaneously transports learning content in small and comprehensible junks. Figure 6.7 shows the Information Agent advising the player, never to say "No" in a dialogue with a Japanese man or woman.

Also the player's avatar can be seen as a story-based agent. Although it is controlled from a first-person view and thus never visible, it acts as a powerful mediator of learning content. By looking at objects and triggering interactions, information is transferred to the user in an inconspicuous way. So, learning occurs as an incidental consequence of the game activity, also called "stealth learning" [Johnson et al., 2007].

The Element of Fun

During the design process we played special attention to keep the level of fun during gameplay as high as possible. The most successful feature for a video game, as well as for a serious game, is the player's enjoyment [Bellotti et al., 2009]. As previously stated, over 80 percent of serious game developers, educators and researchers rate the "element of fun" as important or very important [Michael and Chen, 2005]. Existing serious games that deal with teaching cultural awareness, mostly in military context, lack of funny elements that are so important for the player's motivation and thus for the success of the game. For the design of ICURA fun was a central point. The game includes funny comments and jokes to make learning an entertaining experience. The importance of fun was also confirmed in the evaluation of ICURA that is discussed in the following chapter.

6.3 Evaluation

Pre-Testing

Before ICURA was ready for an extensive evaluation to examine the learning effect on its players, we conducted several test runs. Within these early tests we were mainly aiming at eliminating logical flaws and issues concerning controls and user interface. The game was played by experienced players and by novice players, who have never before navigated within a 3D virtual environment before. The second group provided the most valuable feedback to us, because in a final state ICURA was intended to appeal to non-experienced gamers as well.

During theses test runs we followed the "think-aloud" approach, as described by [Ramey et al., 2006]. The think aloud protocol is primarily used in the domain of usability evaluation, but can be quite easily adopted for similar applications. Think aloud aims to explore what (in our case) players are thinking and feeling when they're playing a game. The idea is to assign the test person several tasks, which she strives to solve through interaction with the system. She immediately verbalizes every thought that crosses her mind during the session. The result enables the researches to draw various conclusions, for instance what exactly the players learn, if the players are actually engaged or which aspects seem to motivate or disturb the players. We conducted several think-aloud sessions of about 40 minutes each. The only instruction we gave was to play the game until the end. The following list is an excerpt of findings we gained during these sessions:

- Some of the inspect/interact texts still were a little bit unclear or anticipated some information.
- In an earlier version, the Information Agent sometimes failed to raise the attention of the player when new information was displayed. We changed this by adding visual and auditive notifications.
- It was easily possible to fall from a virtual bridge in the game. This actually didn't "harm" the player, but it was considered as annoying. We counteracted this by adding invisible collision walls on both sides.
- Novice players had problems with controlling the mouse and the keyboard at the same time. Especially the mouse-look functionality caused some trouble. By default, we deactivated mouse-look in later versions. It can be toggled by pressing the tab key.
- People had problems to understand the "combine" functionality in the inventory.
- When the player takes and puts on the slippers in front of the Japanese temple, the 3D model of the slippers didn't actually disappear. The players missed some meaningful feedback by the game. In a later version, the object actually disappears from the 3D world, accompanied by an auditive feedback.

Evaluation Method and Goals

The actual evaluation of ICURA was conducted in March 2010 and a total of 20 participants were invited to play the game. The overall goals of the evaluation include the following questions:

- How much information does the game communicate?
- What do people associate with the term "serious game"?
- Is the game fun to play and is the design of the 3D environment considered as convincing?
- Does ICURA spark the interest in Japanese culture?

Figure 6.8: The evaluation setting for ICURA, March 2010

A very common approach to analyze the effectiveness of Serious Games is the comparison of pre- and post-test results to highlight the learning effect [Adamo-Villani and Wright, 2007, Bellotti et al., 2009, Eagle, 2009, Gustafsson and Bång, 2008, Marsh et al., 2005, Sheng et al., 2007]. In addition, questionnaires are used to collect demographic data and to detect strengths and weaknesses in game design and usability. A more extensive approach splits up the test group into an experimental group that plays the game, and a control group that is taught using prevalent methods such as classroom teaching [Henderson et al., 2008, Eagle and Barnes, 2009].

The evaluation for ICURA was carried out in five steps. In the pre-questionnaire, demographic data and information about the participant's computer usage habits was collected. Afterwards the pre-test was completed to have a baseline measure of knowledge about the Japanese culture. Then ICURA was played and the post-test was taken. The last step was a final questionnaire to determine the overall satisfaction with the game. On average, it took 15 minutes to finish ICURA, however, with a little bit guidance. The average duration of one session was 33 minutes. The evaluation of ICURA was announced in advance at Vienna University of Technology and on several Internet boards. It proofed difficult to find enough people that were willing to come to our institution and participate in the evaluation. But after all, 20 persons agreed to test the game. The evaluation setting is depicted in Figure 6.8, a summary of the results is shown in the Appendix on page A.8.

Results of the Pre-Questionnaire

The original version of the pre-questionnaire is depicted in the Appendix on page A.4. A total of 20 users participated in the evaluations of which four were female and 16 were male. On average they were 29 years old (Mean (M) = 29,35; Standard Deviation (SD) = 4,49). The youngest test

person was 21 years old and the oldest was 43. Most of them were heavy computer users with an average computer usage of 41 hours per week (M = 40,7; SD = 17,42). 15 participants ranked their computer skills as either "good" or "very good" (M = 4,15; SD = 0,93, assuming that 1 is beginner and 5 is expert). So the study is clearly biased. Despite our expectations, the time they spend playing video games is comparatively low, with a mean of 3,15 hours a week (SD = 1,53). Nine participants enjoy to play games "much" or "very much", but nearly all of them mentioned, they lack of time to play games. Regarding the term "serious game", nine have never heard it before, the rest associated it with learning and education. One called it an "oxymoron", because "a game can never be serious". All in all the confidence in computer games as mediators for knowledge is very high (M = 4,35; SD = 0,67), but they think learning games in general are moderately interesting (M = 3,35; SD = 0,88). 18 people show a "high" or "very high" interest in foreign cultures (M = 4,40; SD = 0,68), three of those have been to Japan once before. They are moderately interested in the Japanese culture (M = 3,05; SD = 1,00).

Results of the Post-Questionnaire

The post-questionnaire is shown in the Appendix on page A.5. Directly after playing ICURA and taking the post-test, every participant was asked to do a final questionnaire. The overall fun-factor of the game was rated high, with a mean of 4.20 (SD = 0,70). So our efforts to integrate elements of fun into the game seemed to pay off. No one said that playing the game makes no fun at all. The participants enjoyed the state-of-the-art graphics, the winterly landscape, the overall atmosphere, the humor and the learning content in general. Especially the integrated dialogue system was highlighted for its intuitive handling. One participant said the game reminds him of the classic adventure games like *Monkey Island* and he felt like being in Japan. People mainly criticized the controls of the game. When pressing the left or right arrow keys, they expected the avatar to perform a sideway motion (called "strafing"), instead of turning into a direction. Although the game lets the player toggle the mouse cursor to activate a mouse-look view, scarcely anybody made use of it. Some participants criticized the lack of this function. So, this demonstrates that we took too less effort to explain the controls. One way to counteract this problem is to design a tutorial level to introduce the player into the game. As a rule of thumb and to avoid unpleasant surprises, it is best to stick to prevalent control principles, as they are used in current 3D first- or third-person action games. ICURA also lacks of voice output so far. As Moreno says, "students learn better when words are spoken rather than printed" [Moreno, 2006]. The difficulty of ICURA was ranked as adequate (M = 3,10; SD = 0,64, where 1 is "too easy" and 5 means "too difficult"). All in all 19 people think that the 3D World of ICURA is authentic and gives a feeling of being in Japan (M = 4,74; SD = 0,45).

One important issue was the evaluation of the Information Agent. We took great effort to direct the player's attention to the text box. As soon as it displays new information, the speech bubble blinks three times and an alert sound is played. 19 participants noticed, when the Information Agent changed its state. Only one person did not recognize it. The same person also had major problems with navigating the avatar through the 3D World and felt overstrained. So, it would be useful to implement a *Beginners Mode* for those, who feel uncomfortable within the 3D World that slowly introduces the player into the game. In general, a user interface should be highly efficient, good looking and non-intrusive [Yue and Zin, 2009]. The Information Agent

was not perceived as too intrusive (M = 1,26; SD = 0,56, where 1 means “not intrusive at all”). 16 people thought, the information from the Agent are “important” or “very important”, because they are applicable to real-life situations. No one thought, they were of no importance. 14 participants would play the game again to answer all 12 questions in the test correctly and thus reach a higher final score. Those, who would not play it again think that they would not acquire new knowledge. 15 participants said, they would be interested in games like ICURA in private life (M = 3,94; SD = 0,57) and the game also sparked their interest in the Japanese culture (M = 3,55; SD = 0,94).

Results of the Pre- and Post-Test

The results of the Pre- and Post-Test demonstrate, how much information the game communicates. Both tests consist of twelve questions, ten single-choice (one out of five is correct) and two multiple-choice questions (more than one can be correct). Four questions deal with language basics, four with behavioral rules and etiquette and the rest covers topics of culture and society. The test, as it was integrated into the game, is depicted in the Appendix on pages A.1 - A.3. The correct answers are printed in boldface. Pages A.6 - A.7 show detailed tables of the test-results.

As Figure 6.9 depicts, every participant was able to improve his results after having played ICURA. On average, 5.05 questions were correct at the Pre-Test (SD = 1,99). This value grew up to exactly 10 at the Post-Test (SD = 1,26). Two people were able to answer everything correctly. A paired t-test showed that the difference is considered to be extremely statistically significant (the two-tailed P value is less than 0,0001). A static or negative learning outcome would have potentially pointed to problems with the design of the questions or the tasks to provide a learning outcome [Marsh et al., 2005]. So, the evaluation shows that ICURA successfully communicates information about Japanese culture and etiquette. But there are significant differences in how the information is presented to the player within the game.

Following the constructivist learning theory, a big part of the learning content is designed as an integrated part of the puzzles in the game. The player has to deal with the learning content actively to fulfill a task. Other information was just displayed by the Information Agent, without compelling the user to deal with it actively. The analysis of both tests show that information that follow constructivist principles is communicated much more effective than others. To give an example, before playing the game only four people knew how to salute an older and respectful person in Japan (by using the suffix *-sensei*). Afterwards everyone was able to answer this question correctly because the user had to apply this knowledge in order to proceed in the game. See question 5 in Figure 6.10 that visualizes the number of correct answers to the twelve test questions. On the other side, the language basics, like how to say “Hello” and “Thank You” in Japanese (Question 1 to 4 in Figure 6.10) were communicated worse than expected because the user just read the information on screen without any connection to a meaningful action. In addition, four people mentioned that the learning content itself could have been of greater importance. In this case, it would have been crucial to cooperate with external experts to find out, which information about Japanese culture and etiquette is considered as most important to the user.

6.4 Summary and Discussion

ICURA is a 3D Adventure Serious Game that provides an opportunity to learn more about Japanese culture and etiquette. ICURA can be seen as a practical guide to living in Japan. The main goal of the game is to combine aspects of learning and fun in an immersive 3D environment to make the communication of knowledge an entertaining experience. To sum up the results of the evaluation, the term *serious game* is still new to many people. Those, who heard about it, associate it with learning and educational games. ICURA was rated as very funny to play, the 3D environment is convincing and it did spark interest in the Japanese culture. Concerning the communication of knowledge, ICURA was successful, even though there is still room for improvement. It is recommendable to wrap the story of the game around the learning content and to integrate every information into a puzzle to force the player to deal with it. One major issue for critique is the design of the test questions in general. First of all, the two multiple choice questions turned out to be designed too difficultly. For example, consider question 11 in the Appendix on page A.3, most test persons checked two answers correctly (Shinto and Buddhism) but did not check the third correct answer, Syncretism (which is the combination of two or more religious belief systems into a new system). For this reason the answer was rated as wrong. So these multiple choice questions somehow failed to check the player' knowledge gain during playing ICURA. Another issue concerns the overall design of the pre- and post-test. Both tests comprise the same twelve questions. One could argue that the player may remember these questions from the pre-test, wittingly or unwittingly, and pays special attention to find the correct answers during gameplay. This phenomenon is called "selective attention", or more specific, "confirmation bias". The term "confirmation bias" was coined by English psychologist Peter Wason and describes the tendency of people to favor information that confirms their beliefs or hypotheses [Wason, 1968]. We tried to counteract confirmation bias by presenting the test questions, as well as the answers, from the pre-test in a different order than in the post-test. We are aware of the fact that this step didn't completely exclude confirmation bias from our evaluation, but it was helpful to some extent. An alternative method could comprise to mislead the player's mind by designing a pre-test that contains lots of questions that are not actually answered in the game. Therefore the player cannot focus his mind on finding the answers to questions of importance. These two lessons learned provide a valuable basis for future work.

Making a game about the Japanese culture was a first thematic testbed. Possible alternatives could be a game about Singapore, China or Islamist countries - in general countries that presume some prior knowledge to get fully immersed in genuine local culture. Making learning scenarios for different countries is a possible directions for future work and future research. In Chapter 8 we will discuss the challenges that appeared during the design process of ICURA and which lessons we have learned from them. These experiences provided a valuable basis for the design of the second artifact presented in this thesis, ThIATRO.

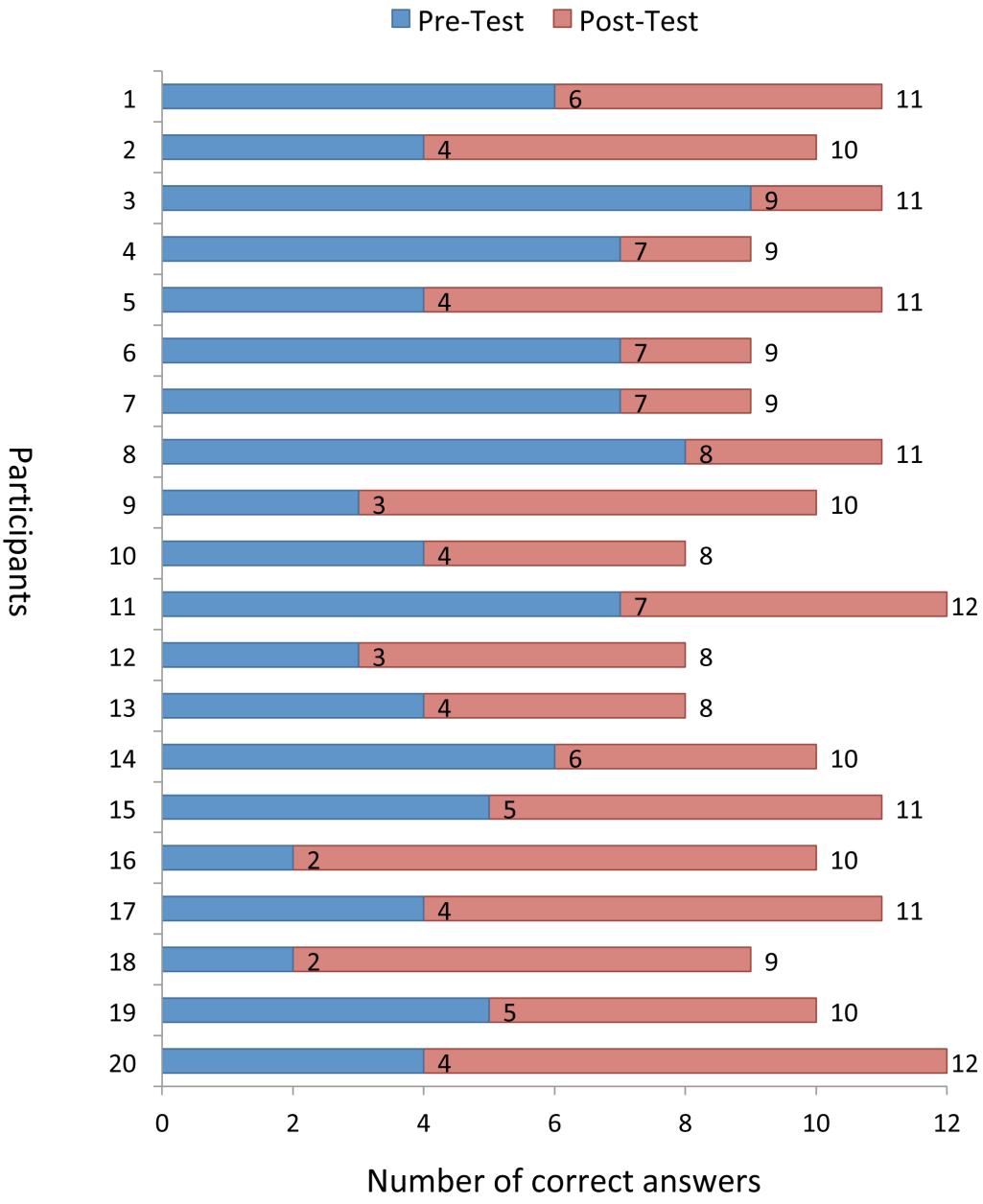


Figure 6.9: Number of correct answers per player in the pre- and post-test. Blue: pre-test, red: post-test

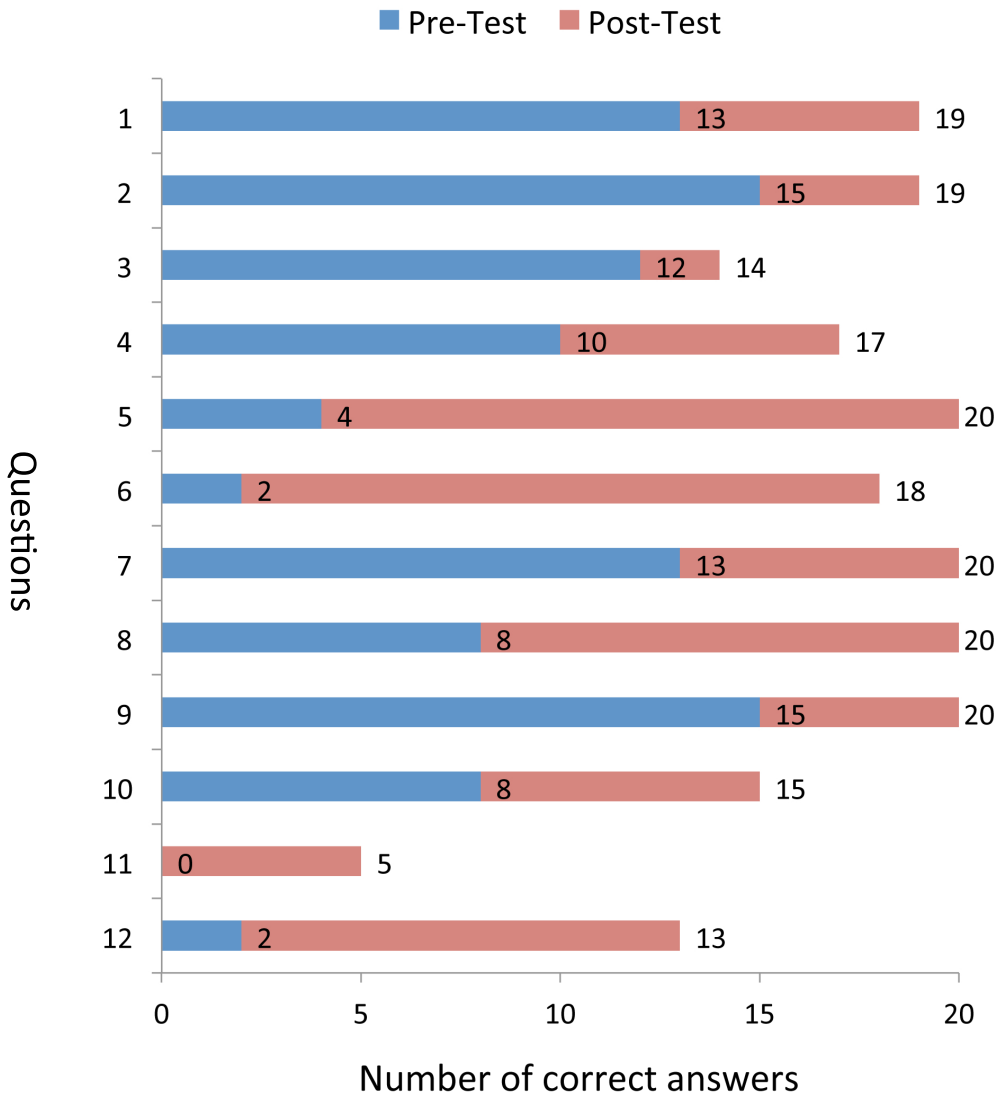


Figure 6.10: Total number of correct answers to the 12 test questions in the pre- and post-test phase. Blue: pre-test, red: post-test

CHAPTER 7

ThIATRO - The Immersive Art Training Online

"Games are art! Art is impressionistic, narrative, emotional, intellectual... such as games." (Raph Koster, 2004)

In Chapter 1 of this thesis we have defined games as an essential component of all human culture, although they still struggle for acceptance because they are perceived to solve no cultural or social function [Newman, 2004]. With the practical example from the last Chapter, ICURA, we were aiming at resolving this misconception by making a game that includes a clear cultural function. In the introductory citation of this Chapter, Raph Koster describes games as a form of art because both areas share the same characteristics. For him, there is no doubt that games are a part of modern culture. Also Michael and Chen refer to games as an "artistic medium to deliver a message, teach lessons, or provide an experience" [Michael and Chen, 2005]. Games like *Shadow of the Colossus* (Team Ico, 2006, see Section 3.4) or *Limbo* (Playdead, 2010) are often referred to as "Art Games" because of their unique, unconventional look and their extraordinary design. In this Chapter we deal with the serious game ThIATRO (**Th**e **I**mmersive **A**rt **Tr**aining **O**nline) that fosters an understanding of cultural heritage in the discipline of art history. Note that ThIATRO is no art game, but a game about art history. We harness the motivational power of digital games to raise the player's interest in art historical concepts. As a continuation of the artifact presented in the last Chapter, we are now dealing with tangible (or physical) goods of cultural heritage. These include buildings, monuments, landscapes or, central to our work, paintings. We provide an overview of our design ideas and summarize the results of evaluations conducted with students at university and a group of 14-year-old pupils in classroom environment. The results indicate that ThIATRO changes the player's aesthetic response and allows her to perceive art on a deeper level.

7.1 A Quick Look at ThIATRO

One major motivation for the research behind this thesis includes finding new ways of raising the interest of children and young adults in their cultural heritage. This curious generation normally comes into contact with art history in school for the first time. The curriculum for art classes in Austria's grammar schools includes two central teaching aims: to foster the the abilities in visual/applied arts and to raise the interest in art history and contemporary culture. Considering that art education is a compulsory subject until the 6th grade in Austrian grammar schools (when pupils are 16 years on average) and from that moment on an elective subject, important fields of art history are often only touched peripherally. In addition, a major part of the teaching time is focused on learning practical crafts (such as painting techniques) and theories about aesthetics and chromatics. It is vital to create an entertaining and hands-on learning experience for pupils to deepen their understanding for art history.

We have stated that serious games can be a source of enjoyment and, if well-made, are a powerful tool to communicate knowledge. Recent projects, as presented in Chapter 5, deal with information and communication technologies and cultural heritage. They blaze new trails for knowledge communication by making use of 3D modeling techniques, graphics and animations to breathe life into historic sites. However, virtual heritage applications often lack interactivity and innovative storytelling techniques to captivate their audience and raise interest in the field of cultural heritage. To overcome these shortcomings, recent works tend to enrich their 3D virtual worlds with game elements in order to make learning about cultural heritage more entertaining. Unfortunately, game design principles (as exemplarily described in Table 3.1 on page 28) are often not obeyed strictly enough to fulfill the requirements for a good learning game. When browsing through online and mobile games dealing with cultural heritage, especially art-historical content, we can see that most applications are simple memory games, puzzles or quizzes that check the learner's knowledge on a very basic level[1]. These games are limited to teaching about the connections between an artist and his or her associated works of art. Instead, the focus of development should be directed towards the development of games that compel the player to think about, organize and use information in ways that encourage active construction of knowledge and deepen art appreciation. Matters are aggravated by the fact that art historical facts per se can be tedious to communicate, especially when it just concentrates on teaching artists names, artworks and their corresponding era of art. It is vital to create an entertaining and hands-on learning experience for students to learn art history.

These observations led us to the development of the 3D online learning game ThIATRO that aims at teaching the player to examine and understand paintings instead of communicating hard facts. ThIATRO immerses the player into a virtual 3D exhibition and raises motivation by creating a meaningful learning environment for art historical concepts. The game raises the curiosity to engage with art to create a persistent idea of art historical concepts.

[1] see for examples the iPhone/iPad applications *Art Museum*, *Art Puzzle* or *Art Quiz for iPad*

Goals of ThIATRO

In Chapter 4.5 we mentioned James Paul Gee's idea of "semiotic domains". To recall this concept, a semiotic domain means a sector of social life that isolates itself by means of communication and the symbols that are used (such as language, writing or signs). Art history is a very good example of a semiotic domain. Experts describing a painting often use very specific technical expressions and phrases. Especially when it comes to identifying, describing and interpreting the content and symbols of an image (called *iconography*), they tend to use a language that differs a lot form common everyday speech or the language of lay persons (in matters of art history). Only people, who are acquainted with the scientific field of art history (people who are "socialized" in the field), are able to understand their language with all its subtleties. In order to successfully teach a topic, so Gee, learners have to be introduced, and therefore socialized in the corresponding semiotic domain. And this is exactly one goal of ThIATRO: to socialize its players in the semiotic domain of art history. In the long run, the player becomes a part of the same "affinity group" of art historians. As we have heard, this socialization process stands at the beginning of every successful computer game, an analogue process is completely missing in traditional classroom teaching. For this reason, ThIATRO is intended to be used by art teachers as a gentle starting point to communicate some basic concepts to socialize its players in the semiotic domain of art history. Its playful approach aims at raising interest in art history and cultural heritage in general. Game design follows the principle of "stealth learning", where learning occurs as an incidental consequence of the game activity [Johnson et al., 2007]. ThIATRO seeks to accomplish the following:

- combine learning and fun in an immersive 3D environment to make the communication of art historical facts more entertaining,
- create a game-like environment that fosters a lively learning experience as an incidental consequence of the game activity,
- raise interest in art history, culture and cultural heritage.

ThIATRO is part of the project "The Virtual 3D Social Experience Museum" [2]. The principal goal of this project is to connect the diversified fields of art history and computer science by novel means of technology. VŠEM aims at communicating art history to a wide audience of experts and lay persons at the same time. In succession, the developed tools shall help to support the bidirectional interaction between museums and their visitors. A detailed description of VŠEM and its project members was already given in Chapter 1.2.

3D Learning Environments for Art History

In Section 6.1 we have stated that using 3D virtual worlds for a serious game adds a range of difficulties concerning controls and hardware requirements. And despite these known issues Hedberg et al. [Hedberg and Alexander, 1994,Dalgarno and Hedberg, 2001] highlight the ability of 3D virtual environments to situate the learning within a meaningful context to a much greater

[2] `http://vsem.ec.tuwien.ac.at/`, last accessed: May 2, 2012

Figure 7.1: The 3D world of ThIATRO and a virtual museum showing Baroque art

extent than traditional interactive multimedia environments. In the case of an art history learning game, we want to immerse the player into an exhibition by recreating 3D virtual museums (see Figure 7.1). The game temps to awaken the feeling of standing in a real-world exhibition. We belief that this 3D approach raises the curiosity to engage with art and thus creates a lively and persistent idea of art historical concepts in the player's minds. ThIATRO allows for the creation of personal collections of paintings and lets the player capture the experience of walking through an own (virtual) museum. The player can see, how paintings influence the atmosphere of a room. Of course, a game can never fully reproduce the impression of a real-world exhibition, but it still can produce some kind of "placeness". By now, ThIATRO exclusively deals with 2D artworks (paintings). For future work, it will be interesting to integrate 3D artworks (like sculptures or architecture) in the game and thus fully exploit the possibilities of an additional dimension.

7.2 ThIATRO - A Detailed Description

Walkthrough Scenario

ThIATRO is a treasure hunt game about art history that can be played online in the web browser[3]. The ThIATRO webpage displays a short introductory text and German and English versions of the game. The actual game starts by choosing between two control schemes, one for beginners,

[3] `www.thiatro.info`, last accessed: May 2, 2012. The website also offers a 23MB download package for offline playing

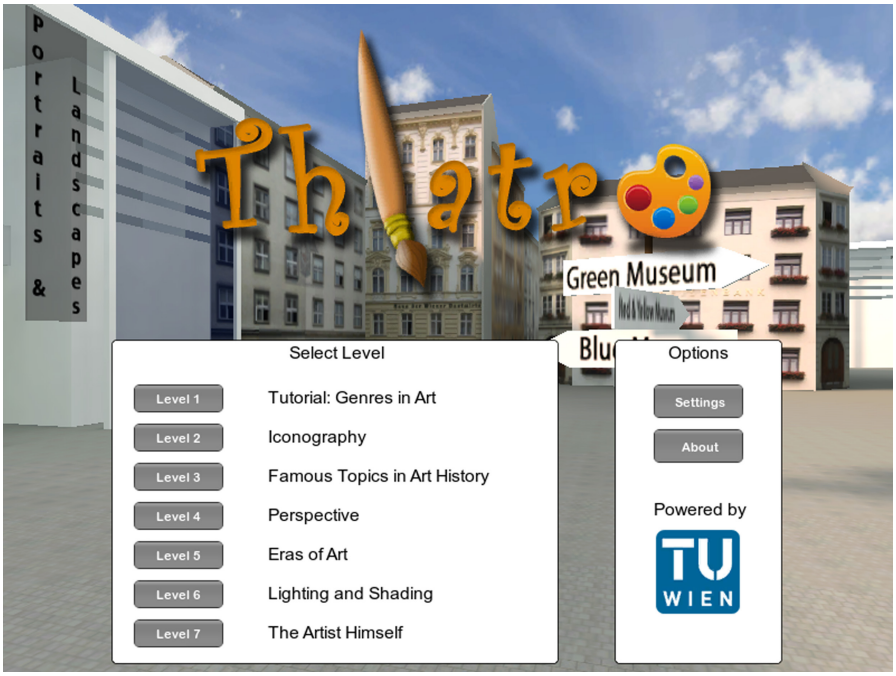


Figure 7.2: The main menu of ThIATRO. The player can choose between seven levels.

who have never played 3D games before, and one for advanced gamers, who are familiar with navigating in 3D worlds (see Chapter 7.2). While the main content of the game is streamed via the Web, the player can already explore the virtual world to acquaint herself with the controls. A status bar at the bottom of the screen displays the loading process. At an average connection speed, it takes about 30 seconds to load the whole content. As soon as the status bar reaches 100%, the main menu appears that lets the player choose from seven different levels. In addition she can change some settings concerning graphics quality, mouse sensitivity and walk speed. Figure 7.2 shows the main menu screen.

The game's plot allows the player to slip into the role of a museum curator. In a fictive town resembling the inner districts of Vienna, we placed four museums that exhibit different paintings (see Figure 7.4 on page 82). Each museum focuses on a specific era or subject matter, as indicated by a banner on the outside of the museum (e.g., "The Art of Baroque" or "Religious Art"; see Figure 7.1). In each level, the player must search for paintings in the four museums to fulfill the task of arranging an exhibition around an art-historical concept. A typical level description is shown in Figure 7.3. Collecting paintings happens by approaching a certain artwork and pressing a key to take the picture. The painting then appears as a thumbnail in the progress bar at the top left corner of the GUI and as real-size version in our own museum. At the end of the level, the player can examine her own collection, together with metadata about the paintings she has collected.

The first level does not assume any art-historical knowledge. Instead, it makes the player deal with art and its genres in a beginner-friendly way. Paintings in art history are traditionally

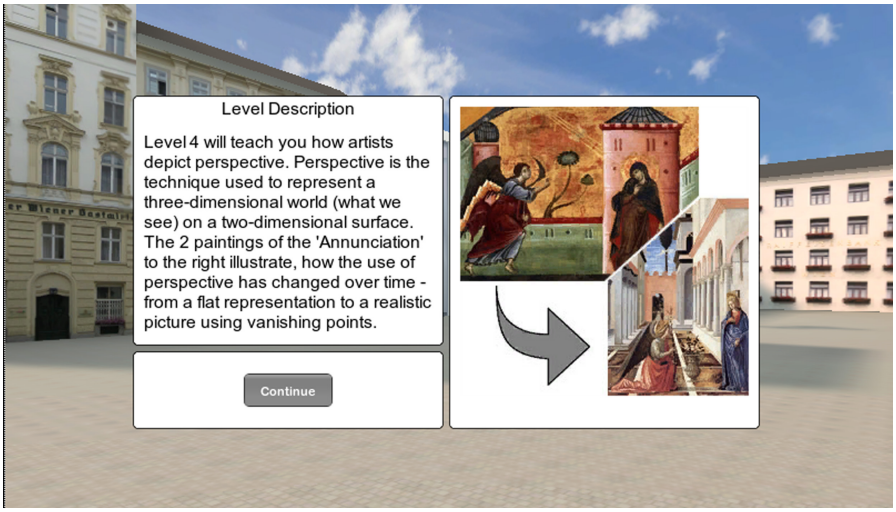


Figure 7.3: Level 4 makes the player deal with perspective in art history.

divided into five categories: portraits, landscapes, still-lifes, history or religious paintings and genre scenes. In level one, the player collects one example from each category. As soon as she has brought the paintings together, she is directed back to her own museum to inspect her personal exhibition. The player learns (from level to level): genres in art history, iconography, famous topics in art, composition and perspective, eras of art history (from the Middle Ages to the Baroque), facts about lighting and shading and, finally, how to use the information learned in previous levels to identify a specific painter or artistic era.

Design Process

It took about 12 months to finish ThIATRO, starting from the first idea until the game reached a level that was ready for evaluation. Similar to the design of ICURA we started by agreeing on the thematic framework and then thought about genre choices, core mechanics and rules.

Prensky underlines the importance of finding "the lowest common denominator game format" [Prensky, 2001a]. Based on his classification of learning activities and their recommended game genres, we have taken the following decision: ThIATRO's main concept is based on "creativity" and "observation". According to Prensky, this leads to the learning activities "memorization" and "feedback". For these activities, he proposes puzzles and concentration games. Based on the recommendations, we decided to present the learning content in form of an treasure-hunt game that lets the player search for specific paintings, investigate them, and take decisions according to some feedback. We continued defining the core mechanics of the game. To recall its definition, Salen and Zimmerman's define them as "the essential play activity players perform again and again in a game" [Salen and Zimmerman, 2003]. The core mechanics of ICURA can be summarized as follows:

- Probing the virtual world by means of *looking around* (mouse movement), and *moving*

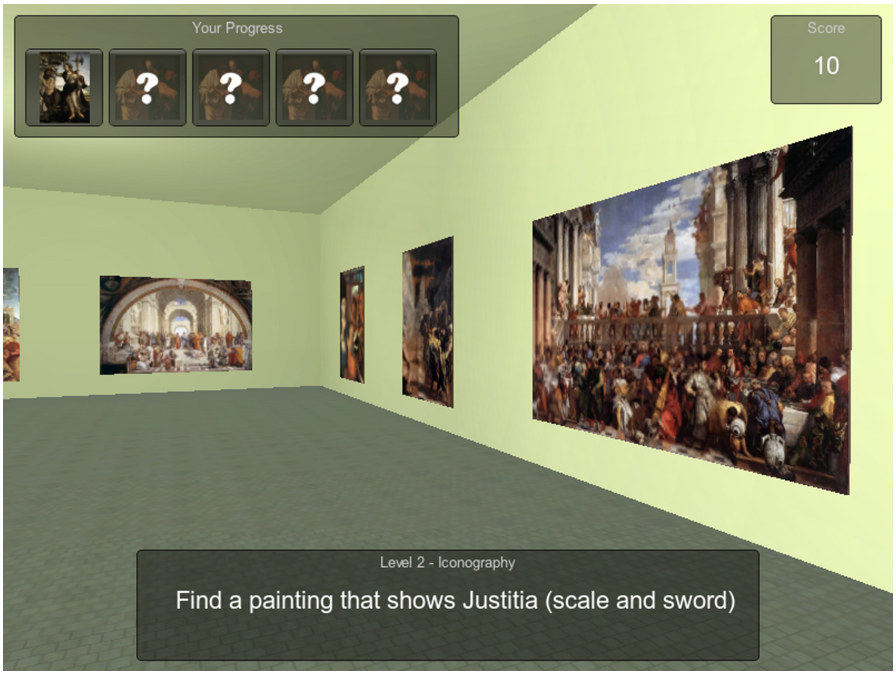


Figure 7.4: A virtual museum exhibiting paintings in ThIATRO.

(cursor or WASD keys)

- *Investigating and comparing* artworks according to certain tasks.
- *Recalling* knowledge from previous levels to fulfill these tasks.

The rules of the game are straight-forward. In order to finish a level, five paintings that fulfill the assigned task have to be collected. 10 points are assigned for a correct choice, 5 points are subtracted for a wrong choice. As soon as the task is fulfilled, the player returns to her own museum and enters the next level.

The development of ThIATRO was planned to be a cross-disciplinary process from the very beginning. We met with art historians to discuss their opinions of the game. They advised us not to presuppose any knowledge and to slowly familiarize the player with art-historical concepts. Each game level concentrates on a specific and very basic topic. The introductory texts are kept as short as possible. Concerning the plot of the game, we initially designed ThIATRO as a game that lets the player slip into the role of an art-thief that steals paintings to fulfill her client's mission. The same idea was also presented at 2010's EVA Conference (Electronic Information, the Visual Arts and Beyond). Art historians in the audience suggested to turn down this idea because it is ethically not justifiable to educate children as art-thiefs. For this reason we changed the plot of the game to the effect that the player becomes a curator instead, collecting paintings for her client.

Technical Background

Similar to the previous Chapter's artifact, we will now give a detailed description of technical issues.

Unity3D

To become acquainted with commercial game engines is a time-consuming process. In addition, most high-end game engines are very expensive. One goal of this project is to demonstrate that state-of-the-art serious games can be implemented with no (or few) expenditures on the core technologies. Thus, we sought a low-cost game engine that fulfills all of our needs. Based on the lessons we have learned from the design of ICURA, we wanted to create a state-of-the-art 3D game that runs in the user's browser window to make it widely available and to keep the access barrier low. Torque game engine (that was used for the implementation of ICURA) still didn't provide all the means to publish the game online on Windows and Macintosh. For this reason we chose to implement the game in Unity3D [4], which was the de-facto game development standard at the time of creation. Unity is a game engine and authoring tool for creating 3D games or other interactive content such as architectural visualizations or real-time 3D animations. Unity development environment (and the games it produces) run on Windows and Mac and is free in the basic version. For us Unity was the first choice because its support for producing browser games via the Unity web player plugin. Game scripting can be done with Unity Script (similar to JavaScript), C# or Boo. Since most of the tutorials and documented sample games are implemented with Unity Script, we chose to follow their example. Figure 7.5 shows a screenshot of Unity. The main screen is called *Scene View* and displays the actual game. The two bars at the right show the *Hierarchy View*, which lists all the assets in the scene, and the *Editor*, listing a currently selected game script.

3D Virtual World Design

Our goal was to create a state-of-the-art 3D game that runs in the user's browser window to make it widely available and to keep the access barrier as low as possible. For that reason, we had to keep down the polygon count while nevertheless giving the game a unique and appealing visual style. We started by taking pictures of typical Viennese house fronts with a *Canon EOS 500D* DSLR camera and a 17mm wide-angle lens. The horizontal perspective and distortion were then corrected in *Adobe Photoshop* to obtain useful textures for our 3D models. The whole modeling process was carried out in *Google SketchUp*[5]. SketchUp is a 3D modeling software, designed for architectural, civil and mechanical engineers as well as game designers. Compared to other 3D modeling tools, SketchUp is much easier to learn and provided the possibility to quickly design prototypical 3D objects for ThIATRO. In addition, it is free in the basic version. Since the basic version does not support Unity's fbx. format, we had to update to a time-limited pro version for exporting the 3D models. In the final version of the game, we use no more than ten different house-textures to guarantee that the 3D environment loads quickly and still looks diversified.

[4] `http://www.unity3d.com/`, last accessed: May 2, 2012

[5] `http://www.googlesketchup.com/`, last accessed: May 2, 2012

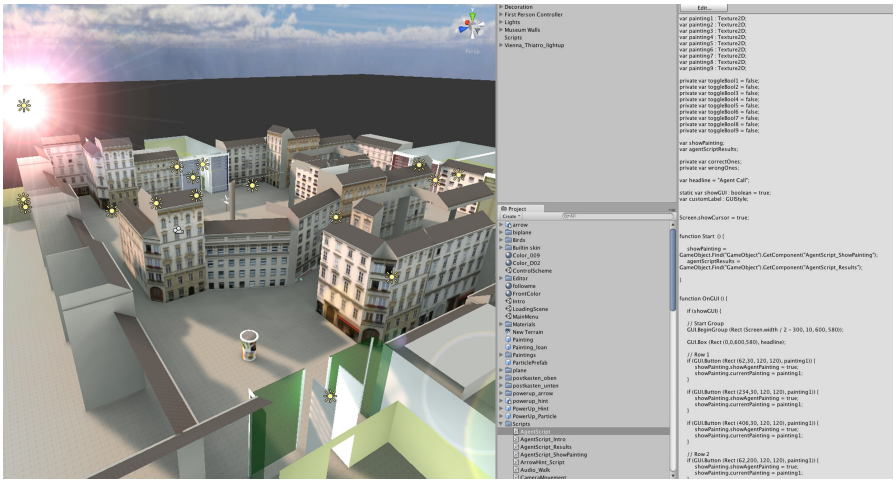


Figure 7.5: ThIATRO was implemented with UNITY Game Engine The screenshot shows the 3D model of the virtual city, a list of assets and a Unity script.

Figure 7.6: Ten different textures were used for the virtual buildings in ThIATRO

Figure 7.6 shows all ten textures after correcting horizontal perspective and distortion. We took great care to only model those parts of the virtual city that are actually visible to the player in order to minimize polygon count and thus avoid performance loss (see Figure 7.8). The final version was later augmented with decorating 3D elements like mailboxes, an advertising column and two tunnels that act as shortcuts between the virtual museums.

In order to further immerse the player into the 3D world and thus create a vivid learning environment, we wanted to make the virtual city and the museums as visually appealing as possible. Unfortunately, the basic version of Unity does not support elaborate algorithms like real-time shadows, light-mapping or post-processing effects. Furthermore effects like these are computationally expensive, particularly with a view to making an online game that should run smoothly in the player's browser window. Instead of packing the game full of expensive calculations dur-

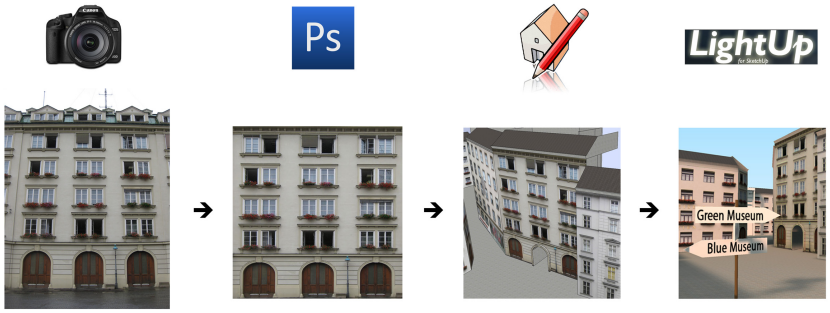


Figure 7.7: The workflow of creating the 3D world - Step 1: taking pictures of housefronts, Step 2: correcting horizontal perspective and distortion in Adobe Photoshop, Step 3: modeling and texturing in Google SketchUp, Step 4: adding realistic lighting effects in LightUp for SketchUp and export scene to Unity.

Figure 7.8: A screenshot of the final low-polygon 3D model from Google SketchUp

ing runtime, we were looking for tools that allow us to pre-calculate the lighting situation and shadows of our 3D environment. We finally came upon *LightUp*, a SketchUp plugin that adds realistic lighting effects to the SketchUp scene. We placed various light sources in the 3D world to create an indirect and diffuse light and an uniform lighting atmosphere. LightUp stores the corresponding light information and shadow-maps and exports them together with the actual 3D models as fbx. file. The 3D model of this fictitious city was then imported to Unity Game Engine, which provides functionality for the online architecture and gameplay elements. Lanterns, tunnels and point light sources were added to the level to create a special atmosphere. The virtual city has a size of approximately 250 x 200 meters. A visualization of the design process and a screenshot of the final low-polygon 3D model are depicted in Figure 7.7 and Figure 7.8.

Data Source

ThIATRO can be viewed as an art museum that displays artworks in a hands-on manner. We chose to use the *Web Gallery of Art*[6] as a well-known data source of classic paintings for our in-game museums. This data collection features information on approximately 18,000 different works of art by approximately 2,200 (mostly European) artists. It covers the period between approximately 1100 and 1850. ThIATRO includes information on the eras of Middle Ages, Renaissance and Baroque. Tables B.1 to B.8 in the Appendix of this thesis list all the paintings that appear in the game. We chose these specific (and mostly famous) paintings because they incorporate typical characteristics of these important art historical ages. The artworks from the WGA underly the same protective regulations for intellectual property like any other intellectual work. The copyright ends 70 years or less after the death of the creator. In the case for ThIATRO, copyrights for the works in the WGA have already expired and thus are publicly available and free to use by anyone.

Each of the four museums in the game shows a predefined set of ten paintings that stay the same at every level (see Appendix B.1 for a complete list). In an early prototype we were thinking of varying the paintings for every level, resulting in altogether 280 paintings. We quickly discarded this idea and reduced the number of paintings because of two reasons. First of all, the loading times for every level grew up to an annoying level. And, even more important, with this large number of classical paintings we were running risk of overwhelming the player with information, especially when we consider that the average player is new to art history. As we will see in Chapter 7.3, reducing the number of paintings also helped the players to remember paintings from previous levels and establish meaningful connections between tasks and the artwork's location.

Controls and User Interface

From the very beginning of the design process we published prototypes of ThIATRO on our website, announced it on social networking platforms and asked users to provide us with feedback on usability, game design and bug reports. In addition, we organized test sessions following the "think-aloud" approach, as described by [Ramey et al., 2006] and as already outlined in Chapter 6.3. These steps turned out to be crucial to the future design because the feedback helped us understand the expectations and needs of our target group. The following Section gives a summary of our design steps based on the community's feedback.

Mark Prensky highlights the importance of considering a "diversified audience" for a learning game [Prensky, 2001a]. During the design process of ICURA we disregarded this rule to some extent and acted on the assumption that everyone has navigated within a 3D world before. As we have seen in the evaluation, some players were unable to cope with controlling keyboard and mouse at the same time and thus were distracted from the actual learning content. We took too less effort to offer an alternative control scheme for beginners and we didn't stick close enough to prevalent control paradigms. When designing the controls for ThIATRO we adhered closely to the conventions of common 3D games to make it easy to get started. The avatar is controlled from a first-person perspective by using the mouse and the WASD keys. For players

[6] `http://www.wga.hu/`, last accessed: May 3, 2012

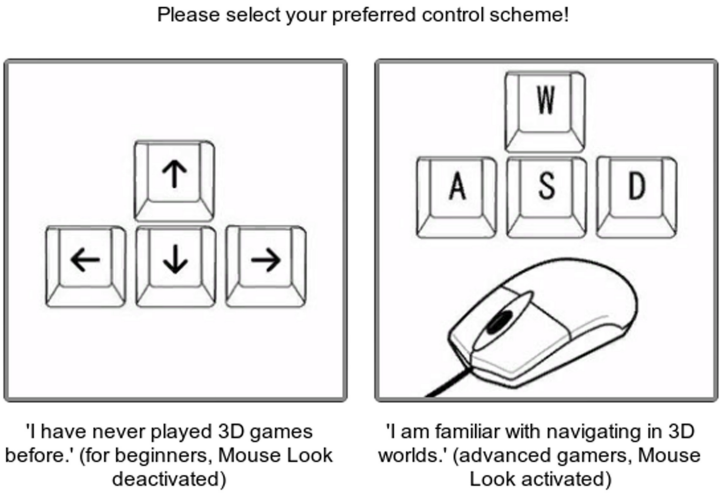


Figure 7.9: The game offer two control schemes. Left: beginners, right: advanced players

who have never navigated an avatar in a game before, we offer a simplified control scheme that deactivates the mouse look and allows avatars to walk around simply by pressing the cursor keys (see Figure 7.9). In addition, the player can already explore the virtual world to acquaint herself with the controls before the actual game starts.

The user interface of ThIATRO is kept very simple. The design was mainly driven by the requirement that interface elements must not distract the view on the artworks. Thus we decided to let the player choose if the GUI is displayed or not by pressing the TAB key. Figure 7.4 shows a screenshot of ThIATRO and the GUI elements. The top left displays a progress bar with thumbnails of the paintings we have collected so far. The top right shows the current score, where 10 points are assigned for a correct choice and 5 points are subtracted for a wrong choice. At the bottom we see the level name and a description of the current task. In an earlier version of ThIATRO some players complained about becoming lost in the 3D world and being unable to find the way to the virtual museums. We addressed this problem by integrating a mini-map into the GUI that can be accessed by pressing the “m”-key. The mini-map simply shows the sight angle of a second top-down camera directed on the virtual city. The player’s position is highlighted as a red spot. Another important decision was taken concerning the metadata about the paintings. We decided to hide the creator, title and year of creation of all paintings by default. This step should make the player exclusively deal with the painting itself and not with information about the painting. On demand the metadata can be displayed by pressing the “i”-key when standing in front of a painting. An additional GUI element assists the player in the first level. We integrated a red three-dimensional arrow that guides the player to the first museum. This step can be seen as an initial in-game tutorial to acquaint the player with the 3D world. The same red arrow appears at the end of every level to direct the player back to her own museum to have a look at the collected artworks.

Design Principles

Integration of Learning Content

ThIATRO acts as a learning tool for fundamental concepts of art history. In detail, the player learns (from level to level) genres in art history, iconography, famous topics in art, composition and perspective, eras of art history (from the Middle Ages to the Baroque), facts about lighting and shading and, finally, how to use the information learned in previous levels to identify a specific painter or artistic era, in our case *Michelangelo Merisi da Caravaggio*. Following constructivist learning theory, learning content is embedded in context. the learner has to actively deal with it to advance in the game. The most central tenet of constructivism is that learners should be engaged in active exploration, they should be intrinsically motivated, and they should develop an understanding of a domain through challenging and enjoyable problem-solving activities [Piaget, 1964]. ThIATRO aims at teaching the player to examine and understand paintings instead of teaching hard facts. As already mentioned in the previous Chapter, the issue is not starting players with easy cases. The issue is starting them with cases that are basic or fundamental in the sense that they lead the learner to discover and practice what are, in fact, fruitful patterns and generalizations. Fruitful patterns and generalizations, according to Gee [Gee, 2003] are ones that allow the learner to make real progress in the domain and that can serve as the correct basis of good guides for more complicated patterns and generalizations that need to be discovered later by confronting more complex and less-basic situations and cases. ThIATRO immerses the player into a virtual 3D exhibition and raises motivation by creating a meaningful learning environment for art historical concepts that provides the basis for future knowledge. The game raises the curiosity to engage with art to create a persistent idea of art historical concepts.

The ThIATRO player is able to explore and manipulate the virtual environment and view art galleries in the museum buildings. In addition, we organize the material into small and comprehensible chunks to avoid overwhelming the player with information. Each museum in the game shows a predefined set of paintings that stay the same at every level. In our first user study with a small test group, we observed that by level four, players noted that certain paintings could be found in the Renaissance museum, without previous knowledge of the art-historical era of the Renaissance. At level six, they went directly to the Baroque museum to complete their painting selections. This finding indicates that the player learns to establish a connection between the task and the artwork's location and confirms the function of collateral learning. As explained by Gee, the player probes the virtual world, forms hypotheses about what something might mean in a usefully situated way and then reprobes the world with that hypothesis in mind, seeing what effect he or she gets. The player treats this effect as feedback from the world and accepts or rethinks his or her original hypothesis [Gee, 2004]. If the player takes a wrong painting choice that does not match the current task, feedback is given in form of an audio signal ("NO!"). The other way round a correct choice is approved by a clear "YES!". In order to check the player's knowledge during gameplay, we added the basis for an in-game evaluation. At the end of level 3 ("Famous topics in art history"), the player gets a virtual phone-call by her client, who suggests to choose additional paintings from a set of presented artworks. If the player chooses those paintings that fulfill the level's task, she earns some extra points. This in-game evaluation is prototypically implemented and provides an additional chance for the player

Figure 7.10: Left: A power-up in front of the player, right: a veil of color revealing the position of the searched paintings

to gather knowledge on previously presented learning content.

Power-Ups

In ThIATRO each of the four museums deals with a specific era of art (e.g. Baroque) or a specific topic (e.g. religious art). The idea behind this design decision was to create connections between the title of the museum (as indicated by the banner on the outside) and the shown paintings in the inside. In other words, we wanted to map eras and topics of art to our 3D virtual world and thus create meaningful connections in the player's minds. However, first test sessions showed that some players found it annoying that the distances between the museums were long and the space between them was unused. So we came up with the idea to augment the space between the virtual museums with the well-known game design concept of *power-ups*. Power-ups are objects that instantly benefit or add extra abilities to a game character. In ThIATRO, these objects are scattered randomly around the map and appear/disappear at intervals of 30 seconds. In the current version we have designed two types of power-ups. The first one provides the player with some additional information on the searched painting. The second one reveals the target's position by showing a veil of color in front of the paintings for ten seconds (see Figure 7.10).

7.3 Evaluation

Evaluation Method and Goals

After revising the major points of critique provided by the community and the think-aloud test-sessions, ThIATRO was ready for an extensive evaluation. Since the game is intended to be used by art teachers as a gentle starting point to art historical concepts, the evaluation was conducted in classroom environment. There are two prevalent approaches to analyzing the effectiveness of serious games. The first one makes use of pre- and post-test results to determine learning success. A more extensive approach splits the test group into an experimental group that plays the game and a control group that is taught using prevalent methods, such as classroom discus-

Figure 7.11: Students at Vienna University of Technology playing ThIATRO

sion. General questionnaires are used to collect impressions of the strengths and weaknesses in the game design and usability. We decided to choose the control group/experimental group approach for this artifact because we wanted to observe the game in direct comparison with prevalent teaching methods. The evaluation was conducted in April 2011 at the "Europagymnasium Baumgartenberg", an Austrian middle school. Twenty 14-year-old students participated in the test session. We chose this specific school because we had personal contact to Susanne Schatz, art teacher and head of the class. She agreed to support us with the evaluation and reserved a 2-hours time window for the evaluation in April 2011. In addition, she gave valuable support while teaching the control group.

Before beginning the classroom evaluation, we conducted a test run with a group of 15 computer science students in the context of a lecture on cultural heritage informatics at Vienna University of Technology to ensure that the following approach fits into a two-hour timeframe (see Figure 7.11). Note that the results of this pre-evaluation cannot be directly compared to the final evaluation in school environment since the game was still in development then. Nevertheless, the results of this "pre-evaluation" can be found in the Appendix on pages B.12 - B.13.

Coming back to the actual evaluation, the class was split randomly into an experimental group that played ThIATRO and a control group, which was taught the same content by their classroom teacher. In order to gain insight into the learning success of ThIATRO, we had to check the art-historical knowledge of the pupils before and after playing the game as well as before and after the teaching session. Asking art-historical facts (such as "Which artist painted this picture?" or "When was it painted?") would not have led to the desired results because the game does not communicate hard facts. In fact, ThIATRO teaches players to read and understand paintings and thus changes the way they perceive art. To successfully evaluate the game, we had to find ways to measure the participants' perceptions of art before and after the test session. An

Figure 7.12: Pablo Picasso, Girl before a Mirror (1932)

appropriate model was proposed by [Housen, 2007]. The "Stages of Aesthetic Development" provide a method of determining how a person feels about art and how to measure this response. According to this method, people are asked what comes to their minds when seeing a certain painting. Each idea, association, pause and observation is transcribed and analyzed, and the interview is then classified according to the five Aesthetic Stages. To clarify this approach, let us examine Picasso's *Girl Before a Mirror* (see Figure 7.12).

- Stage 1: Viewers are list-makers and storytellers. They make simple, concrete observa-

tions. In Picasso's painting, a Stage 1 viewer may say: "*I see lines, ovals and squares*" or "*The wallpaper is beautiful.*"

- Stage 2: Observations include the knowledge of the natural world and the values of their social and moral world. ("*The hair on the first person is blond, and that is true, but there is no such thing as a purple face.*")
- Stage 3: Viewers start identifying the work by artist, school, style, time and provenance. ("*This one could be by Picasso.*")
- Stage 4: Viewers allow the meaning of the work, its symbols, emerge. ("*The color red is a symbol for aggression.*")
- Stage 5: Viewers have established a long history of viewing and reflecting about art. ("*I remember, when I first looked at this painting years ago ...*")

Each aesthetic stage is characterized by a knowable set of interrelated attributes. We decided to use the aesthetic stage model for our evaluation because it provides a reliable method of measuring a participant's perception of art. The hypothesis tested in the evaluation can be summarized as follows: "ThIATRO changes the player's aesthetic response and allows her to perceive art on a deeper level".

To gain insight into the pupils' aesthetic stage of art perception, we asked them to look at three paintings before and after the test sessions. The paintings we used for evaluation are depicted in the Appendix on pages B.17 - B.18. We chose these specific paintings because they incorporate typical characteristics of the important art historical eras of Middle Ages, Renaissance and Baroque. Due to time constraints during the evaluation, it was not possible to conduct extensive interviews with every participant. Instead, we asked them to write down whatever came to their mind and to assign keywords to each painting. Each keyword, or tag, was then classified according to the aesthetic stages presented above. See Figure 7.13 for an excerpt of the EXCEL file that was created for the evaluation. As an example, tags like "haggard man", "dying woman" or "blood" are simple, concrete observations. The viewers are list-makers. By tagging a painting with the term "permanent learning" ("ständiges Lernen')' the viewer brings some personal feeling into her observation and thus reaches aesthetic stage 2. Observations such as "vanishing point", "color perspective" and "Hieronymus" assume some art historical knowledge and go beyond simple observations. Viewers start identifying the work by artist, school, style, time and provenance and thus reach stage 3. Note that aesthetic stages 4 and 5 were not relevant for the evaluation because they suppose a longer history of viewing and reflecting about art that cannot be expected from 14-years old pupils.

The two groups' results were then compared to investigate the changes in aesthetic response. The evaluation itself was carried out in five steps. A pre-questionnaire collected demographic data and information about general interests in art history and computer gaming habits. Afterwards, students were asked to assign tags to three paintings, ranging from the Middle Ages to the Baroque period. The class was then split up randomly into an experimental group that played ThIATRO and a control group that discussed the same learning content with their classroom teacher. After a 30-minute playing/teaching session, another set of paintings was described by

the students (paintings that did not appear in the game/discussion), and a final questionnaire was taken. The evaluation took two hours altogether. Figure 7.14 and 7.15 show the experimental and the control group during the evaluation.

Results of the Pre-Questionnaire

The pre-questionnaire for "Europagymnasium Baumgartenberg" can be found in the Appendix on page B.9. A total of 20 pupils participated in the evaluation, eight males and twelve females. On average, they were 14 years old. Most of them spend between one and three hours per day in front of the computer. More than two-thirds of them play computer games on a daily basis or even several times a day, mainly on PCs, consoles or mobile phones. Almost none of the participants play card or board games. Sixteen students consider themselves beginner or advanced video gamers, and four consider themselves experts. We asked them whether they considered learning games as interesting as conventional games and the results were, according to our expectations, quite low (mean (M) = 2.75; standard deviation (SD) = 0.85, assuming that 1 is "totally disagree" and 5 is "totally agree"). The misconception remains that learning games can never be fun. As Bellotti et al. state, people tend to perceive games that are not primarily targeted at entertainment as boring [Bellotti et al., 2009]. On the other hand, most of the students do believe that games are a good tool for communicating knowledge (M = 3.45; SD = 0.89). In general, the students share a moderate interest in art history (M = 2.65; SD = 1.18), and only five of them enjoy visiting museums (M = 2.7; SD = 1.13). The results can be revised on page B.14.

Results of the Post-Questionnaire

After a 30-minute gaming/teaching session, both groups filled out another questionnaire to evaluate their overall satisfaction with the tested learning methods. We asked them if they enjoyed playing the game or discussing the paintings with their teacher. The experimental group (playing ThIATRO) rated the level of fun very high with a mean value of 4.60 (SD = 0.52). Unsurprisingly, the results for the control group were a bit lower, with an average of 3.90 (SD = 0.74). This finding indicates that we successfully integrated elements of fun into the game. The usefulness of teaching art history within games (M = 4.20; SD = 0.92), or alternatively with discussion of paintings (M = 4.30; SD = 0.48), was rated high by both groups. In other words, the students accepted both teaching approaches. The most successful learning games aim to motivate the learner for a long time, even at home in their spare time. We asked both groups whether they would continue learning about art history. Pupils from the control group did not show great interest in continuing to deal with the subject area (M = 2.2; SD = 0.79). ThIATRO received a considerably higher score with an average of 3.90 (SD = 0.57). Eight of ten students stated that they would play the game at home again. The game also did a better job of raising the students' interest in art history in general. The experimental group reached an average value of 3.5 (SD = 0.71, control group: M = 3.0; SD = 1.05). Note that by conventional criteria, this difference is considered to be not statistically significant (with a two-tailed P value of 0.2289). We can also see that the standard deviation in the last question was comparatively high and that the values diverged a great deal. Some pupils said they were simply not interested in art history and that the game did not change their attitude. Others felt highly incentivized to keep on work-

ing with art history and rated this question very high. In general remarks about ThIATRO, the pupils positively highlighted the graphics, the controls and the fact that the game can be played directly in the browser window without any noticeable lags. Negative remarks concerned the absence of multiplayer functionality. Some participants said it was a bit boring to explore the 3D world alone. The questions, along with the results of the post-questionnaire (for control and experimental group) can be found on pages B.10 - B.11 an B.15 - B.16.

Results of Tagging the Paintings

In order to test our hypothesis that ThIATRO changes a player's aesthetic response, allowing a person to perceive art on a deeper level, we asked the students to assign tags to three paintings before and after the playing/discussion session. We simply told them to write down whatever came to mind when viewing a specific painting, optimally as catchwords or sentences. Afterwards, each tag was assigned to its associated aesthetic stage. Before the learning sessions, most of the tags were simple, explicit observations of Aesthetic Stage 1, such as woman, book or halo (see Chapter 5.1.1). As Housen states, most adults seldom score above Stage 2 [Housen, 2007], and this is exactly what we saw in our evaluation because scarcely anyone reached Stage 3. Figure 7.16 and Figure 7.17 show the results for the control group and the experimental group in detail.

For example, the students from the control group assigned 97 tags of Aesthetic Stage 1, 30 of Stage 2 and only one of Stage 3 before the 30-minute learning session. Again, note that Aesthetic Stages 4 and 5 were not relevant for the evaluation because they suppose a longer history of viewing and reflecting about art. We then calculated the mean for all tags to obtain an average value of the overall Aesthetic Stage of the class. Before the learning session, the control group reached a value of 1.29, and members of the experimental group had an average of 1.18. Thus, both groups assigned tags on a basic level, primarily writing down what they saw and how they felt about art. After the 30-minute learning sessions, we can see a clear shift to Stage 3 observations from both teaching approaches.

The pupils started to identify the works by artists, schools, time and subject. For example, St. Jerome, a popular motif in Christian art, was recognized by the attributes with which he is most frequently depicted: a skull, a bible and a lion. Knowledge of the iconography made students observe different details in the paintings. If we compare both groups' results, we can see that they are nearly the same: the control group with an average of 2.32 and the experimental group with 2.30. Therefore, both approaches change a person's aesthetic response and allow him/her to perceive art on a deeper level. Neither of the teaching methods shows a significant advantage in communicating knowledge.

7.4 Summary and Discussion

In this Chapter, we presented the online learning game ThIATRO that immerses the player into an exhibition and helps students learn about art history. This playful approach not only increases motivation to learn but also raises interest in art history and cultural heritage in general. Our work provides tools for teachers to use in classrooms and general tools for everyone who wants to gain

knowledge in the area of cultural heritage. We presented our design ideas and the implementation process in detail and provided some helpful guidelines for the design of Serious Games in this field of research. The evaluation showed that ThIATRO changes its players' aesthetic responses, allowing them to perceive art on a deeper level. ThIATRO did not show significant advantages in knowledge communication in comparison with prevalent teaching methods. However, it has the potential to continuously motivate a younger generation to deal with the topic on a user-friendly level. Most students rated the level of fun very high and stated that they would play the game at home again. As a result of playing ThIATRO, many students felt highly incentivized to keep on working with art history, even outside of classroom environment.

The post-questionnaire results show that ThIATRO may inspire learners to work with art history and cultural heritage at home, even in their spare time, and this is exactly the strength of digital game-based learning. Eight of ten students stated that they would play the game at home again. The game also does a better job of raising interest in art history than formal teaching and some pupils felt highly incentivized to keep on working with art history. There is enormous potential in innovative online games that combine entertainment and learning content. The goal is to shake off the bad associations that many users have developed with poorly designed learning games in earlier times. Exclusive game playing in classrooms is not the solution; games will never replace teachers and the novelty effects of 3D virtual learning environments will wear off. However, games are good tools to motivate young people to deal with topics outside of their spheres of interest.

By now, ThIATRO exclusively deals with 2D artworks (paintings). For future work, it will be interesting to integrate 3D artworks (like sculptures or architecture) in the game and thus fully exploit the possibilities of an additional dimension. In addition, the paintings in ThIATRO do not reflect their real-world size because the Web Gallery of Art only include this information for a specific subset of paintings. For reasons of simplicity the artworks in ThIATRO all share the same size. Future plans include integrating multiplayer functionality and an online tool that allows dynamic content to be created to fulfill dynamic learning goals.

Participant 1	Painting 1	AS	Painting 2	AS	Painting 3	AS	Painting 4	AS	Painting 5	AS	Painting 6	AS
Tags	Tod	1	sterbende Frau	1	Horror	1	Verkündigung Mariens	3	Fluchtpunkt	3	Barock	3
	Wissen	1	Wehmut	1	Blut	1	Religionsmuseum	2	Farbperspektive	3	Hieronymus	3
	abgemagerter Mann	1			Verwesung	1					dunkel	1
	ständiges Lernen	2			Mord	1						
					Tod	1						
Average		1,25		1,00		1,00		2,50		3,00		2,33
					Result Before	1,09					Result After	2,57

Participant 2	Painting 1	AS	Painting 2	AS	Painting 3	AS	Painting 4	AS	Painting 5	AS	Painting 6	AS
Tags	ständiges Lernen	2	Engel holt sterbende Frau ab	2	Krieg	1	Verkündigung	3	Fluchtpunkt	3	Hieronymus	3
	abgemagerter Mann	1	Adam & Eva	2	Trauer	1	Religiöse Darstellung	2	Hochzeit ?!!	2	Barock	3
	toter Mann	1			Tod	1	Engel + Maria	2	Farben werden hinten blasser	2	Totenkopf	1
	Wissen	1			Verwesung	1	In einem Raum, aber hell	2			Kontrast	3
					Horror	1					Feder	1
					Leiden	1					Engel	2
					Blut	1						
					Weltuntergang	1						
Average		1,25		2,00		1,00		2,25		2,33		2,17
					Result Before	1,21					Result After	2,23

Participant 3	Painting 1	AS	Painting 2	AS	Painting 3	AS	Painting 4	AS	Painting 5	AS	Painting 6	AS
Tags	abgemagerter Mann	1	traurige Engel	2	Sturm	1	2D	3	Tempel	1	Licht-Schatten-	3
	Wissen	1	schöner Garten	1	Kampf	1	historisch /kirchlich	3	Renaissance	3	italienisch	3
	Tod	1			Tod	1	Engel mit Person	2	Fluchtpunkt	3	Caravaggio?	3
							Engel sagt Maria, dass sie schwanger ist	3	Hochzeit	2	genaue Darstellung	2
							Verkündigung	3				
Average		1,00		1,50		1,00		2,80		2,25		2,75
					Result Before	1,13					Result After	2,62

Figure 7.13: A list of tags assigned during the evaluation and their according aesthetic stage.

Figure 7.14: The experimental group playing ThIATRO in “Europagymnasium Baumgartenberg”.

Figure 7.15: The control group discussing art historical concepts.

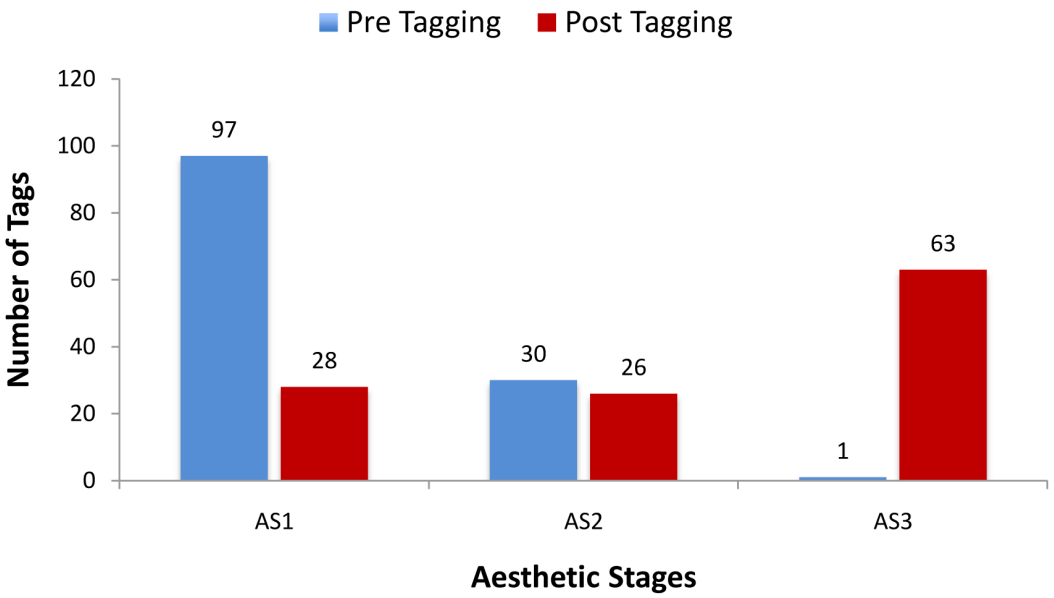


Figure 7.16: Tagging results of the Control Group, average pre: 1.29, average post 2.32

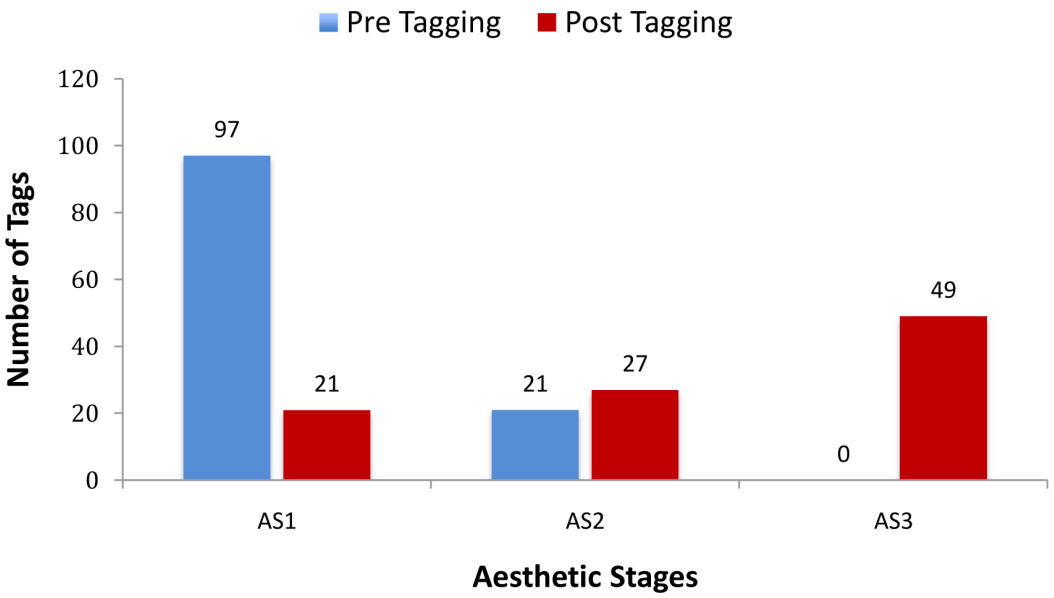


Figure 7.17: Tagging results of the Experimental Group, average pre: 1.18, average post 2.30

CHAPTER 8

Critical Reflection

In order to investigate the possibilities of serious heritage games we have created and evaluated the artifacts ICURA and ThIATRO. This Chapter outlines the challenges we were facing during the design process and which lessons we have learned. These lessons are then summarized in a list of guidelines to assist serious heritage game developers in future projects. We will then resume the central research questions of this thesis (see Chapter 1.1) and give answers on the basis of the design of the two artifacts and the evaluation results. We will conclude with a discussion of open issues.

8.1 Challenges and Lessons Learned

At first glance, ICURA and ThIATRO may be quite different: the one is an offline adventure game immersing the player into Japanese culture, the other presents art historical principles in form of an online scavenger-hunt. But at their core, both games share the same goal of communicating knowledge about cultural heritage in a playful way. The design of ICURA taught us some important lessons. These experiences provided a valuable basis for the design of ThIATRO. We will now discuss these lessons and explain, how we have integrated them into the design of ThIATRO and which general guidelines can be derived from them.

The evaluation of ICURA with 20 participants showed that some aspects are in need of improvement. The main point of criticism concerned the controls of the game. When pressing the left or right arrow keys, they expected the avatar to perform a sideway motion (called “strafing”), instead of turning around the axis. Although the game lets the player toggle the mouse cursor to activate a mouse-look view, scarcely anybody made use of it. This demonstrates that we took too less effort to explain the controls and we didn’t stick close enough to prevalent control paradigms. Another point of critique was related to the communication of knowledge: following the constructivist learning theory, a big part of the learning content was designed as an integrated part of the puzzles in the game. The player has to deal with the learning content actively to fulfill a task. The analysis of both tests shows that information, which follows constructivist principles

was communicated very effectively. Other information was just displayed by the Information Agent, without compelling the user to deal with it actively. Some participants remarked that they did not even recognize these text messages. In ICURA, we have been inconsequent concerning about the constructivist learning theory. In addition, four people mentioned that the learning content itself could have been of greater importance. In this case, it would have been crucial to cooperate with external experts to find out, which information about Japanese culture and etiquette is considered as most important to the user.

After the evaluation, we made the game available for download on our project's website. We also integrated an online highscore that shows the nickname of the player and the results of the pre- and posttests. Contrary to our expectations, the game was hardly played by the public. Reasons could be that people were not willing to download an installer with the size of over 150 MB and the game was simply not announced publicly (besides from the website).

If design standards and guidelines are not strictly obeyed, it is difficult to confirm that serious games really meet the learner's requirements and expectations [Yusoff et al., 2009]. Existing guidelines mostly cover general principles of game design and how to motivate players to play for hours [O´ Broin, 2011]. Recent research deals with guidelines that are tailored to the design of game based e-learning applications. Klopfer et al. for instance list not less than 14 of them [Klopfer et al., 2009]. Based on these guidelines, we suggest a list of eight additional ones to assist serious heritage game-developers in making tools that communicate knowledge in a successful and entertaining way:

- Cross-disciplinarity: The design process of a serious game is significantly influenced by a pedagogical component that must be carefully integrated into the work. Clearly define the learning goals before starting to implement the game and cooperate with experts in the relevant field. Meet with pedagogues to examine the presentation of the information. Make the development of the game a cross-disciplinary process.

- Constructivism: Learning in 3D Worlds follows a constructivist perspective. Central to constructivist theory is the belief that knowledge is constructed, not transmitted, and that learners play an active role in the learning process. Allow the player to deal actively with each learning unit. Wrap the story of the game around the content and integrate every piece of information into a puzzle to allow the player to deal with it directly.

- Obey principles: Stick to prevalent game design principles as they are used in commercial games. When designing navigation for 3D virtual worlds, offer control schemes for both experts and beginners.

- Start from scratch: Do not assume any prior knowledge. Give the player the chance to learn the basics and to use newly gained knowledge. The player must engage with a challenging goal that requires skills, and she must believe that her skills match the challenges of the goal.

- Keep the access barrier low: People are reluctant to download large-scale installer packages before playing an unknown game. If it is possible to play the game within a familiar Web browser, chances are higher that people will give it a try.

- Make it dynamic: Let the user change the content of the game. Provide tools for dynamic content creation that let the tutors (or teachers) create own learning scenarios.
- Make it social: People enjoy to learn together, either as collaborators, or as opponents. Let the learning process become a collaborative (or competitive) experience. Think of integrating the game into a popular social network site. Players can compare scores, challenge friends and even design own learning scenarios for their friends.
- Provide conflict and representation: Integrate exciting narratives, plot-twists or motivating opponents to entirely catch the player's attention.

8.2 Summary and Discussion of the Results

This thesis is grounded on three research questions that have been discussed in Chapter 1.1. We will now give a discussion and critical reflection of these questions.

Research Question 1: Do serious heritage games transfer knowledge about tangible and intangible attributes of cultural heritage?

The first research question deals with the principal ability of games to transfer knowledge and raise interest in the cultural heritage domain. This issue was encountered by the design, implementation and evaluation of two serious heritage games, ICURA and ThIATRO. The first one, ICURA, is targeted at intangible artifacts of cultural heritage and deals with understanding of contemporary culture, learning about language, rules of behavior and etiquette of a specific country. The second one, ThIATRO, communicates concepts of art history and raises the interest in museums and cultural heritage in general. In addition to quantitative evaluations to check the learning outcomes of both games, qualitative questionnaires were used to check the interests in a specific matter before and after playing the games.

The interpretation of the results shows that both games successfully communicated knowledge in their domain. As to ICURA, every participant was able to improve her test results after having played the game. On average, 5.05 (out of 12) questions were correct at the pre-test (SD = 1,99). This value grew up to exactly 10 at the post-test (SD = 1,26). Concerning ThIATRO, the experimental group (playing the game) had an average aesthetic stage of 1.18, thus assigning tags on a basic level (see Chapter 7.3 for a detailed explanation). Primarily pupils wrote down what they saw and how they felt about art. After the 30-minute game-play session we noticed a clear shift to aesthetic sage 3 observations. Pupils started to identify the works by artists, schools, time and subject. By communicating basic, but fundamental concepts of art history, ThIATRO changed the player's aesthetic response and allows him or her to perceive art on a deeper level.

As mentioned above, qualitative questionnaires were used to check the interests in a specific matter before and after playing the games. 18 people (out of 20) showed a "high" or "very high" interest in foreign cultures (M = 4,40; SD = 0,68) before having played ICURA. So the cultural interest was already high before the evaluation. They were moderately interested in the Japanese culture (M = 3,05; SD = 1,00). After the playing session, 9 people stated that the game sparked

their interest in the Japanese culture to a high or very high degree. Only two participants still expressed no interest afterwards. In general, 15 people showed high or very high interest in games like ICURA in their private life. In this regard we only had one bad rating, because the test-person was a non-gamer.

With respect to ThIATRO, we can access and compare information from the control group, who was discussing paintings in classroom environment, and the experimental group, who played the game. In general, the game did a better job of raising the students' interest in art history. The experimental group reached an average value of 3.5 (SD = 0.71, control group: M = 3.0; SD = 1.05). Note that by conventional criteria, this difference is considered to be not statistically significant. We can also see that the standard deviation in this question was comparatively high and that the values diverged a great deal. Some pupils said they were simply not interested in art history and that the game did not change their attitude. Others felt highly incentivized to keep on working with art history and rated this question very high. Eight of ten students stated that they would play the game at home again. We asked both groups whether they would continue learning about art history. Pupils from the control group did not show great interest in continuing to deal with the subject area (M = 2.2; SD = 0.79). ThIATRO received a considerably higher score with an average of 3.90 (SD = 0.57).

To sum up the results, we see serious games as powerful tools to communicate information on cultural heritage related content. Their overall success is determined by the ways how information is embedded into the game itself. This leads us directly to Research Question 2.

Research Question 2: Which means do serious heritage games provide to integrate and communicate knowledge? How do these different means affect the efficiency of knowledge communication?

Research question two investigates ways of knowledge presentation in serious heritage games. This issue was mainly tackled during the design and evaluation of ICURA. We have seen that the game successfully communicates information about Japanese culture and etiquette. But there are significant differences in how the information is presented to the player. Following the constructivist learning theory, a big part of the learning content is designed as an integrated part of the puzzles in the game. The player has to deal with the learning content actively to fulfill a task. Other informations were just displayed by the Information Agent, without compelling the user to deal with it actively. The analysis of both tests show that informations that follow constructivist principles are communicated much more effective than others. To give the example from Chapter 6.3, before playing the game only four people knew how to salute an older and respectful person in Japan (by using the suffix *-sensei*). Afterwards everyone was able to answer this question correctly because the user had to apply this knowledge to successfully get on with the game. Questions 5, 7, 8 and 9 (see Figure 6.10 and Appendix A.1) clearly followed a constructivist perspective and were answered correctly by every participant in the post-test. On the other side, the language basics, like how to say "Hello" and "Thank You" in Japanese were communicated worse than expected because the user just read the information on screen without any connection to a meaningful action. Words and meanings float free and the learners cannot do anything with these words. This insight may not be new, but the evaluation underlined the

importance of encouraging situated and embodied thinking and doing.

So it is crucial for the design of serious games to follow a constructivist path through the learning content. Digital games provide a great basis for integrating information in motivating and meaningful ways - information that will be remembered even years after playing. The creation of long-term knowledge is the most outstanding feature of digital games.

Research Question 3: Are serious heritage games more effective to teach cultural heritage issues that traditional training or classroom teaching?

Research question three raises the issue of the effectivity of serious heritage games in comparison to prevalent teaching methods. As discussed in this thesis, education in school and corporate training is often perceived as non motivating to the games generation and provides hardly any intrinsic motivational factors. We investigated novel ways of teaching in the cultural heritage domain. Research question 3 was mainly tackled by the evaluation of ThIATRO, where we tested the game with a school class of 14 years old pupils and compared the overall efficiency to prevalent teaching methods. If we compare both groups' results, we can see that they are nearly the same: the control group reached an average aesthetic stage of 2.32, whereas the experimental group ended up at 2.30. Therefore, both approaches change a person's aesthetic response and allow him/her to perceive art on a deeper level. Neither of the teaching methods shows a significant advantage in communicating knowledge. But besides from a quantitative outcome, games for teaching imply another important strength. The post-questionnaire results show that ThIATRO may inspire learners to work with art history and cultural heritage at home, even in their spare time, and this is exactly the key to success. We asked both groups whether they would continue learning about art history. Pupils from the control group did not show great interest in continuing to deal with the subject area (M = 2.2; SD = 0.79). ThIATRO received a considerably higher score with an average of 3.90 (SD = 0.57). Eight of ten students stated that they would play the game at home again. There is enormous potential in innovative online games that combine entertainment and learning content. The goal is to shake off the bad associations that many users have developed with poorly designed learning games in earlier times. Exclusive game playing in classrooms is not the solution; games will never replace teachers and the novelty effects of 3D virtual learning environments will wear off. However, games are good tools to motivate young people to step into new fields of their spheres of interest.

8.3 Discussion of Open Issues

ICURA and ThIATRO are prototypes of serious heritage games that are not destined for the free market. Both games incorporate game mechanics and learning content in ways that demonstrate the efficiency of serious games. At the end of the design process, we came up with additional ideas and suggestion for improvement for the design of the games themselves, as well as the evaluation methods. This Section summarizes and discusses possible open issues of the thesis.

Game Content

In Chapter 3.4 we discussed Prensky's six key structural elements that make up a good game: rules, goals, outcome and feedback, conflict/competition/challenge/opposition, interaction and finally representation. Rules, goals, feedback and interaction techniques were discussed in detail for our two artifacts. In terms of conflict and representation, both games are clearly capable of improvement. ThIATRO's and ICURA's storyline do not integrate exciting narratives, plot-twists or motivating opponents to entirely catch the player's attention. As Prensky mentioned, representation is the essence of what makes a game, while others think it is just the "candy" [Prensky, 2001a]. We think that a lively storyline would definitely foster a successful learning process. In this case it would have been of great help to resort to the knowledge of external experts in the fields of Japanese culture (for ICURA) and art history (for ThIATRO) to cooperatively work out exciting and authentic narratives for the games. However, experts in the domains were not sufficiently available to conduct an fruitful interdisciplinary design process. Nevertheless we successfully showed the potential of serious heritage games.

2D versus 3D

ThIATRO exclusively deals with two-dimensional cultural heritage, in our case paintings. It may be interesting to integrate 3D artworks (like sculptures or architecture) in the game and thus fully exploit the possibilities of a 3D virtual world. Of course, the creation of 3D content is a time-consuming activity. In addition, detailed 3D models with high polygon counts quickly lead to a noticeable performance loss, especially in an online browser-game. But, as some recent projects in the related work (see Chapter 5) show, recreation blaze new trails for knowledge communication by making use of 3D modeling techniques, graphics and animations to breathe life into historic sites.

Static versus dynamic

By now, the game content for both games is static, meaning that the user has no direct influence in the learning content that is presented to her. ThIATRO, for example, uses the *Web Gallery of Art* (WGA) as an open data source to display the paintings in the game. In the evaluated version ThIATRO shows the same set of 40 paintings over and over again to reduce loading times, to avoid overwhelming the player with information and to raise a memorization-effect (see Chapter 7.2). An important future step arranges for dynamic content creation (or authoring) tools that lets the tutor (or teacher) compose own learning scenarios that perfectly fits the learner's needs. In the case of ThIATRO, we could make use of the WGA's rich database to let the user choose, which paintings (according to era, style, provenance and artist) she prefers to learn about. This idea was prototypically implemented in the mobile-phone based Android game *ARTournament* and was published in the proceedings of the International Conference on Advanced Learning Technologies 2012 [Froschauer et al., 2012b].

Singe-player versus multi-player

During the evaluation of ThIATRO we were observing pupils playing the game together, helping each other and giving advice where to look for the searched paintings. Although ThIATRO is designed as single-player game, pupils took it for granted to cooperatively make the way through the game (see also [Dede et al., 2004] and [Dieterle and Clarke, 2007]).

This shows some potential to augment the game with a multiplayer functionality. Torque, as well as Unity provide means for the realization of multiplayer-games. ThIATRO (and also ICURA) could highly benefit from the integration of multi-player game mechanics by making the learning process a collaborative or competitive experience. People learn together, either as collaborator, or as opponent. The integration into popular social network sites (like *Facebook* or *Google+*) would bring another interesting and motivating component into the research of serious heritage games. Players compare scores, challenge friends, design their own levels and make their learning progress publicly available.

Flow and reward system

The concept of "flow" was described in Chapter 3.4. For both games we tried to keep the player in flow-state by providing meaningful feedback and granting rewards for her actions. As we have observed during the evaluations, the players keep being motivated for the comparatively short test sessions of about 20 minutes (for ICURA) and 30 minutes (for ThIATRO). However, it is highly unlikely that learners play the games for hours, over and over again. For this reason, an open issue would be to think of ways to keep the player in flow-state, even after a long period of game-play, for example by integrating an efficient reward system. In the case of ThIATRO, we were thinking of ways to enlarge the curator's own museum and augment it with additional content as the game goes on.

Evaluation

Automatic assessment process

In the evaluation process we tested the participants before and after playing the games with separate tests. Michael and Chen say that there is no need to separate the assessment process from the actual game [Michael and Chen, 2005]. The teacher, or the software itself, could identify by the behavior of a student in the game whether he or she understood something or not. The player is interacting with the game while the software is assessing the player and later provides this information to the teacher. For our evaluation this approach would have been difficult because experts in the fields were not available to work out a powerful automatic assessment process. If the games are thought to be integrated as an inherent part in classroom curriculum, then an assessment method like this would definitely be a great help to teachers.

Long-term knowledge

Perhaps the most important open issue in this thesis is to check the impact on long-term knowledge. As Clark C. Abt says, it is all about the creation of long-term knowledge that perhaps

in ten years will still be remembered - knowledge and insights that, in the future course, lead to much better decisions in life [Abt, 1970]. Game have the power to create this kind of long-term knowledge by connecting the learning content with meaningful actions. In our evaluation, we checked the player's knowledge directly after game-play. In order to investigate long-term impact of our artifacts, we would have to repeat the test again after one year, or even later on.

CHAPTER 9

Summary and Future Work

There is no doubt that video games are part of our culture as much as books, movies and other forms of media. Games have historically been the cutting edge of technology [Eagle, 2009] and constantly lead to new developments in the fields of computer graphics, game design and innovative storytelling. However, when it comes to games that are not primarily targeted at entertainment, people tend to perceive those games as boring [Bellotti et al., 2009]. In fact, games have always been a powerful mediator for learning and the novel field of *serious gaming* is getting more and more established in general public and provides new ways of communicating knowledge within a game-like environment. In contrast with typical learning games, serious games cover topics outside of education, such as therapy, politics and art. They go beyond traditional modes of teaching and learning to reach an adult audience.

In this thesis, we have dealt with serious games that foster an understanding of cultural heritage. According to Anderson et al., the use of games to support cultural heritage purposes, such as historical teaching and learning has been less well considered [Anderson et al., 2010]. To fill this gap in research, we have designed and evaluated two *serious heritage games*. The first one, *ICURA*, is targeted at intangible artifacts of cultural heritage and fosters an understanding of contemporary culture, language, rules of behavior and etiquette of a specific country. The second one is called *ThIATRO* and communicates concepts of art history and raises the interest in museums and cultural heritage in general. By this means, we investigate new ways to raise children's and adults' interest in their cultural heritage. Both games were evaluated to check the learning outcomes. For ICURA we gathered 20 participants to play the game and to take part in a pre- and post-test. ThIATRO was tested in classroom environment with 14-year-old students. The class was split randomly into an experimental group that played ThIATRO and a control group, which was taught the same content by their classroom teacher. The results of both groups were compared afterwards. The analysis of the evaluation shows that both games successfully communicated knowledge in their domain. Concerning ThIATRO, neither of the teaching methods (classroom teaching or playing the game) shows a significant advantage in communicating knowledge. But questionnaire results show that ThIATRO may inspire learners to work with art history and cultural heritage at home, even in their spare time, and this is exactly the strength of

games. The evaluation of ICURA clearly showed that there are significant differences in how the information is presented to the player within a game. The analysis of the pre- and post-tests show that informations that follow constructivist principles are communicated much more effective than information that is not embedded in a meaningful context. An important open issue of this thesis is to check the impact on long-term knowledge. As Clark C. Abt says, it is all about the creation of long-term knowledge that perhaps in ten years will still be remembered - knowledge and insights that, in the future course, lead to much better decisions in life [Abt, 1970].

For future work, it will be important to keep on researching the possibilities of digital game-based learning and serious games in the different domains. Raph Koster suggests to "push at some boundaries" and to "produce some work that may shock, or offend" [Koster, 2004]. With this harsh statement he underlines to take risks in research and to cover fields that have been widely untouched by digital game-based learning. In 2003, Mark Prensky talks about his future vision to use mobile platforms to teach and educate their players. He says that mobile technologies are "in place and just waiting for DGBL to happen" [Prensky, 2001a]. Mobile learning enables the user to learn whenever and wherever she wants. There is still a huge research potential to find effective ways to effectively bridge the worlds entertainment games and games for learning purpose. In fact, didactics can learn a lot from the ways how games teach. The main goal is to shake off the bad associations that many users have developed with poorly designed learning games in earlier times. We want to conclude this PhD thesis with a quote from Katie Salen and Eric Zimmerman that exemplary summarizes today's situation of digital games.

> *"If enough people believe that games are meant to be mindless fun, then this is what they will become. If enough people believe that games are capable of greater things, then they will inevitably evolve and advance."*
> (Katie Salen and Eric Zimmerman, 2003)

APPENDIX A

Appendix: ICURA

The appendix includes detailed information about the evaluations of ICURA and ThIATRO. Pages 110 to 112 show the pre- and post-test for ICURA, as it was integrated into the game. The correct answers are printed in boldface. Page 113 and 114 list the questions from the pre- and post-questionnaire. The tables on page 115 and 116 visualize the answers to the test questions, before and after playing the game. Green boxes mark correct answers, red boxes indicate wrong answers. Page 117 finally gives the overall game results of all 20 participants. The last row of the table indicates the duration for the overall evaluation (including gameplay, pre- and post-test and questionnaire time).

Page 119 continues with ThIATRO and shows a list of all 40 paintings that are integrated into the game. Pages 127 to 129 depict the original version of the questionnaire for the pupils at "Europagymnasium Baumgartenberg" (in German, pre-questionnaire, post-questionnaire control and experimental group). Pages 130 to 134 list the results of the evaluation, starting with the student's evaluation at Vienna University of Technology (pre- and post-questionnaire), followed by the pupil's evaluation (pre-questionnaire and separately post-questionnaire for control and experimental group). Pages 135 and 136 finally show the paintings that were used for tagging.

Single Choice / Multiple Choice Test – English Version

Question 1 to 9 are Single Choice, just **one answer** is correct! Question 11 and 12 are Multiple-Choice, **more than one answer** can be correct.

1. How do you say ‚Hello' in Japanese?
    - Nǐ hao
    - Namaste
    - Onegai
    - **Konnichi wa**
    - Sore de kimatta

2. How do you say ‚Good Bye'?
    - **Sayōnara**
    - Zàijiàn
    - Pacim
    - Nei ho
    - Kanpai

3. How do you say ‚Thank You' in Japanese?
    - **Domo Arigato**
    - Dō itashi mashite
    - Shinkansen
    - Sumimasen
    - There is no word for ‚Thank You' in Japanese. Thankfulness is exclusively expressed with gestures.

4. How do you say ‚Yes' and ‚No'?
    - ‚Hai' und ‚Mhai'
    - **‚Hai' und ‚Iie'**
    - , Shi' und ‚Bu shi'
    - , Shi-Tei' und ‚Bu shi-Tei'
    - The words for ‚Yes' and ‚No' are strongly context-sensitive. There are no general terms.

5. You are going to talk to a senior person named *Shotaro* and you want to show high respect for him. Which salutation is the best to choose in this situation?
    - Shotaro-san
    - **Shotaro-sensei**
    - Chan-Shotaro
    - Chin-Shotaro
    - Cho-Shotaro

Figure A.1: Pre- and posttest for the evaluation of ICURA, page 1/3

6. Who or what is ‚Tsutsumi‘?
    - **Describes the art of ‚Gift-Wrapping‘ in Japan.**
    - A name for the head of the family.
    - A typical term for the Emperor's Palace in the center of Tokyo.
    - A collective term for the different bows in Japan. The deeper the bow, the more respect you demonstrate for someone.
    - ‚Tsutsumi‘ means ‚Japan‘ in the national language.

7. You want to enter a temple in Japan, what do you have to keep in mind?
    - To wear traditional Japanese clothing.
    - To wash your hands before entering.
    - Only enter, if the temple priest requests you to do so.
    - To cover as much skin as possible.
    - **To put on the slippers provided at the entrance.**

8. What do you have to keep in mind when talking to a Japanese man or woman?
    - Never address someone directly by name. This might violate the person’s private sphere.
    - **Never say “No” in a dialogue. A clear negation is perceived as impolite.**
    - Never avert your eyes from your dialogue partner. This is an expression of disrespect.
    - To keep the conversation short.
    - As a foreigner, never start a conversation. Always wait for being asked!

9. When you are invited as a guest in Japan, what do you have to keep in mind?
    - Bring money. Also guests in private houses have to pay for the accommodation.
    - Always come a little bit later. So the host has more time to make preparations.
    - Always wear typical Japanese clothing (e.g. a Kimono).
    - **As a guest, it is expected to bring a present, preferably from your home country.**
    - A traditional visit starts with a prayer, usually spoken by the guest.

10. Who or what is ‚Tenno‘?
    - Describes the japanese pufferfish. Only certified cooks are allowed to prepare it.
    - **A name for the monarch of Japan, equal to ‘emperor’.**
    - ‚Tenno‘ is a term for Japanese hospitality.
    - An urban district of Tokio.
    - Teahouses in Japan are called ‚Tenno‘.

Figure A.2: Pre- and posttest for the evaluation of ICURA, page 2/3

Please note! The following questions are Multiple-Choice. More than one answer can be correct.

11. Which religions are prevalent in Japan?
    - **Synkretism**
    - Hinduism
    - **Buddhism**
    - **Shinto**
    - Christinaity

12. What does the color ‚white' mean in Japan?
    - Innocence
    - Envy
    - **Death**
    - **Dolor**
    - Hope

Figure A.3: Pre- and posttest for the evaluation of ICURA, page 3/3

Pre Questionnaire

Question	Type	Options
How old are you?	Textbox	
Sex	Textbox	
How many hours per week do you spend in front of the computer?	Textbox	
How would you rate your computer skills?	5pt Likert	1: beginner, 5: expert
I enjoy playing computer games.	5pt Likert	1: not at all, 5: very much
How many hours per week do you play computer games?	Textbox	
What do you associate with the term "Serious Game"?	Textbox	
(*if no answer: short explanation*)		
Which serious games have you played so far?	Textbox	
Computer games are well suited to communicate knowledge.	5pt Likert	1: totally disagree, 5: totally agree
I think learning games are interesting.	5pt Likert	1: totally disagree, 5: totally agree
I am interested in foreign cultures.	5pt Likert	1: totally disagree, 5: totally agree
How often have you been to Japan?	Textbox	
I am interested in the Japanese culture.		1: totally disagree, 5: totally agree
Which information do you gather before traveling to your destination?	Textbox	
Where do you get these information from?	Textbox	

Figure A.4: Pre-questionnaire for the evaluation of ICURA

Post Questionnaire

Question	Type	Options
I had fun while playing ICURA.	5pt Likert	1: totally disagree, 5: totally agree
What did you like about ICURA?	Textbox	
What did you dislike about ICURA?	Textbox	
What did you like concerning the graphics and the style of the 3D world?	Textbox	
What did you dislike concerning the graphics and the style of the 3D world?	Textbox	
The landscape and the 3D buildings appear authentic to me.	5pt Likert	1: totally disagree, 5: totally agree
What did you like concerning the user interface?	Textbox	
What did you dislike concerning the user interface?	Textbox	
Would you play ICURA again?	Textbox	Yes/No
If no: Why not?	Textbox	
Have you been satisfied with the controls?	Textbox	Yes/No
If no: Why not?	Textbox	
Are you aware of the purpose of the game?	Textbox	
The main goal and the subgoals were clear to me.	5pt Likert	1: totally disagree, 5: totally agree
How would you rate the difficulty of the game?	5pt Likert	1: too easy, 5: too difficult
I was aware of the Information Agent in the upper left corner.	5pt Likert	1: not at all, 5: very much
Did you feel distracted by the Information Agent?	5pt Likert	1: not at all, 5: very much
I consider the communicated knowledge as important.	5pt Likert	1: totally disagree, 5: totally agree
Would you be interested in games like ICURA in your private life?	5pt Likert	1: not at all, 5: very much
Would you prefer to play a game like ICURA to gather information about your destination or do you prefer visiting travel agencies, searching the internet etc.?	Textbox	
Did ICURA raise your interest in the Japanese culture?	5pt Likert	1: not at all, 5: very much

Figure A.5: Post-questionnaire for the evaluation of ICURA

ICURA	Pre-Test Answers											
Participants	Q1 (Hello)	Q2 (Good Bye)	Q3 (Thank You)	Q4 (Yes, No)	Q5 (-sensei)	Q6 (tsutsumi)	Q7 (genkan)	Q8 (No!)	Q9 (present)	Q10 (tenno)	Q11 (religion)	Q12 (color)
1	✓	✗	✓	✓	✗	✗	✗	✓	✓	✓	✗	✗
2	✗	✓	✓	✗	✗	✗	✓	✗	✓	✗	✗	✗
3	✓	✓	✓	✓	✗	✓	✓	✗	✓	✓	✗	✓
4	✓	✓	✗	✗	✓	✗	✓	✓	✓	✓	✗	✗
5	✗	✓	✓	✗	✗	✗	✓	✗	✓	✗	✗	✗
6	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✗	✗
7	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✗	✗
8	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✗	✗
9	✗	✓	✗	✗	✓	✗	✗	✗	✗	✓	✗	✗
10	✗	✗	✗	✓	✓	✗	✓	✗	✓	✗	✗	✗
11	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✗	✗
12	✗	✗	✗	✓	✗	✗	✗	✓	✗	✓	✗	✗
13	✓	✓	✓	✓	✗	✗	✗	✗	✗	✗	✗	✗
14	✓	✓	✓	✗	✗	✗	✓	✓	✓	✗	✗	✗
15	✗	✓	✓	✗	✓	✗	✓	✗	✗	✓	✗	✗
16	✗	✗	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗
17	✓	✓	✗	✗	✗	✗	✓	✗	✓	✗	✗	✗
18	✓	✗	✗	✗	✗	✗	✓	✗	✗	✗	✗	✗
19	✓	✓	✓	✗	✗	✗	✗	✗	✓	✗	✗	✓
20	✓	✓	✗	✗	✗	✓	✗	✗	✓	✗	✗	✗
Correct	13	15	12	9	4	2	13	8	15	8	0	2
Wrong	7	5	8	11	16	18	7	12	5	12	20	18

Figure A.6: Pre-test results of ICURA

ICURA	Post-Test Answers											
Participants	Q1 (Hello)	Q2 (Good Bye)	Q3 (Thank You)	Q4 (Yes, No)	Q5 (-sensei)	Q6 (tsutsumi)	Q7 (genkan)	Q8 (No!)	Q9 (present)	Q10 (tenno)	Q11 (religion)	Q12 (color)
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗
2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗
3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓
4	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✗
5	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗
7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗
8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓
9	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
10	✗	✓	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓
11	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12	✓	✓	✗	✓	✓	✗	✓	✓	✓	✓	✗	✗
13	✓	✗	✗	✗	✓	✓	✓	✓	✓	✓	✗	✓
14	✓	✓	✓	✗	✓	✓	✓	✓	✓	✗	✓	✓
15	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓
16	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✗	✓
17	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓
18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗
19	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓
20	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Correct	19	19	14	17	20	18	20	20	20	15	5	13
Wrong	1	1	6	3	0	2	0	0	0	5	15	7

Figure A.7: Post-test results of ICURA

ICURA	Game Results				
Participants	Nr. Correct Pre	Nr. Correct Post	Score	Time Game (Min.)	Time Overall (Min.)
1	6	11	365	21	40
2	4	10	406	16	33
3	9	11	507	12	25
4	7	9	347	18	35
5	4	11	381	21	40
6	7	9	438	12	29
7	7	9	401	15	33
8	8	11	487	13	36
9	3	10	403	17	36
10	4	8	278	23	36
11	7	12	538	12	28
12	3	8	389	14	34
13	4	8	414	14	29
14	6	10	454	15	33
15	5	11	484	13	32
16	2	10	438	15	32
17	4	11	454	15	31
18	2	9	398	15	34
19	5	10	480	12	37
20	4	12	489	16	31
Mean	5,05	10,00	427,54	15,45	33,20
Standard Deviation	1,99	1,26	61,83	3,19	3,82

Figure A.8: A summary of game results with 20 participants

APPENDIX B

Appendix: ThIATRO

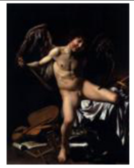
Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Baroque	1	CARAVAGGIO	Amor Victorious	1602-1603	Barock	Historien	Caravaggio, Chiaroscuro	
	2	CARAVAGGIO	St Jerome	1606	Barock	Sakral	Hieronymus (Bibel, Totenkopf, Einsiedler)	
	3	CARAVAGGIO	The Cardsharps	1596	Barock	Genre	Caravaggio	
	4	HEEM, Jan Davidsz. de	Still-Life	1642	Barock	Stillleben	Gattung: Stillleben	
	5	HONTHORST, Gerrit van	The Procuress	1625	Barock	Genre	Chiaroscuro, Anhänger Caravaggios	

Figure B.1: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Baroque	6	PITTONI, Giambattista	The Penitent Magdalene	1740	Barock	Sakral	Magdalena (Totoenkopf, Bibel, Kruzifix)	
	7	RUBENS, Pieter Pauwel	Adoration of the Magi	1626-1629	Barock	Sakral	Thema: Anbetung der Könige, imposantes Licht	
	8	RUBENS, Pieter Pauwel	Raising of the Cross	1610	Barock	Sakral	Chiaroscuro	
	9	STEENWIJCK, Harmen	Vanitas Still-Life	1640	Barock	Stillleben	Gattung: Stillleben	
	10	VERMEER, Johannes	A Lady Drinking and a Gentleman	1658	Barock	Genre	Gattung: Genremalerei, Zentalperspektive	

Figure B.2: A List of 40 paintings that are integrated into ThIATRO

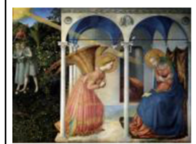
Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Renaissance	11	BOTTICELLI, Sandro	Pallas and the Centaur	1482	Renaissance	Historien	Minerva und Centaur, Farbperspektive	
	12	CARNEVALE, Fra	The Annunciation	1448	Renaissance	Sakral	Thema: Die Verkündigung, Sakral, schöne Perspektive	
	13	DÜRER, Albrecht	Adoration of the Magi	1504	Renaissance	Sakral	Anbetung der Könige, Farbperspektive	
	14	ANGELICO, Fra	The Annunciation	1430-1432	Renaissance	Sakral	Thema: Die Verkündigung, Zentralperspektive	
	15	MASSYS, Quentin	The Adoration of the Magi	1526	Renaissance	Sakral	Thema: Anbetung der Könige, Farbperspektive	

Figure B.3: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Renaissance	16	PERUGINO, Pietro	Famous Men of Antiquity	1497-1500	Renaissance	Historien	Justitia (Waage und Schwert)	
	17	RAFFAELLO Sanzio	The School of Athens	1509	Renaissance	Historien	Linearperspektive	
	18	TINTORETTO	The Stealing of the Dead Body of St Mark	1562-1566	Renaissance	Sakral	Linearperspektive	
	19	VERONESE, Paolo	The Family of Darius before Alexander	1565-1570	Renaissance	Historien	Farbperspektive	
	20	VERONESE, Paolo	The Marriage at Cana	1563	Renaissance	Sakral	Linear- und Farbperspektive	

Figure B.4: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Religious	21	CARAVAGGIO	The Calling of Saint Matthew	1599-1600	Barock	Sakral	Chiaroscuro	
	22	CARAVAGGIO	The Conversion on the Way to Damascus	1600	Barock	Sakral	Gattung: Sakral	
	23	CIMABUE	Madonna Enthroned with the Child	(unkn.)	Renaissance	Sakral	Bedeutungsperspektive	
	24	COSSA, Francesco del	Griffoni Polyptych: St John the Baptist	1473	Renaissance	Sakral	Johannes der Täufer (Stock, Lamm, Fell, Echse)	
	25	ANDREA DA MURANO	Polyptych	1478	Renaissance	Sakral	Bedeutungsperspektive	

Figure B.5: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Religious	26	DUCCIO di Buoninsegna	Pilate Washing his Hands	1308-1311	Byzantinisch	Sakral	Falsche Perspektive	
	27	GRECO, El	The Annunciation	1570	Renaissance	Sakral	Thema: Die Verkündigung, Sakral, Perspektive	
	28	ANGELICO, Fra	Adoration of the Magi	1433-1434	Renaissance	Sakral	Thema: Anbetung der Könige	
	29	GUIDO DA SIENA	Annunciation	1270	Byzantinisch	Sakral	Thema: Die Verkündigung, Sakral, keine Perspektive	
	30	RENI, Guido	The Penitent Magdalene	1635	Barock	Sakral	Magdalena (Totoenkopf, Kruzifix)	

Figure B.6: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Portraits and Landscapes	31	BRIL, Paul	Fantastic Landscape	1598	Renaissance	Landschaft	Farbperspektive	
	32	BRUEGHEL, Pieter the Younger	Winter Landscape with a Bird-trap	none	Renaissance	Landscape	Farbperspektive	
	33	CARAVAGGIO	Sick Bacchus	1593	Barock	Historien	Caravaggio	
	34	DAVID, Jacques -Louis	Napoleon in his Study	1812	Klassizismus	Historien/ Portrait	Chiaroscuro	
	35	LEONARDO da Vinci	St John the Baptist	1513-1516	Renaissance	Sakral	Chiaroscuro	

Figure B.7: A List of 40 paintings that are integrated into ThIATRO

Museum	Nr.	Artist	Title	Year	Era	Type	Comments	Thumbnail
Portraits and Landscapes	36	DÜRER, Albrecht	Self-Portrait at 26	1498	Renaissance	Portrait/ Landschaft	Leichte Farbperspektive	
	37	MASOLINO da Panicale	Banquet of Herod	1435	Renaissance	Historien	Linearperspektive	
	38	REMBRANDT van Rijn	Self-Portrait	1627	Barock	Portrait	Chiaroscuro	
	39	TURNER, Joseph William	Dutch Fishing Boats in a Storm	1801	Romantik	Landschaft	Gattung: Landschaft	
	40	VERMEER, Johannes	Girl with a Pearl Earring	1665	Barock	Portrait	Gattung: Portrait	

Figure B.8: A List of 40 paintings that are integrated into ThIATRO

Fragebogen Teil 1 – Europagymnasium Baumgartenberg

1. Allgemeine Informationen

Geschlecht	☐ männlich ☐ weiblich
Wie viele Stunden verbringst du täglich vor dem Computer?	☐ 0-1 Stunden ☐ 1-3 Stunden ☐ 3-5 Stunden ☐ mehr als 5 Stunden
Wie oft spielst du Computerspiele?	☐ nie ☐ monatlich ☐ wöchentlich ☐ täglich ☐ mehrmals täglich
Ich selbst halte mich in Bezug auf Computerspiele für einen...	☐ Anfänger ☐ Fortgeschrittenen Spieler ☐ Profispieler
Womit spielst du? (mehrere Antworten möglich)	☐ PC / Mac ☐ Konsole (Xbox, Wii, PS3...) ☐ Tragbare Konsole (Nintendo DS, PSP...) ☐ Handy ☐ Karten- / Brettspiele

2. Bitte zutreffendes ankreuzen

	Trifft überhaupt nicht zu	Trift wenig zu	Unentschlossen	Trifft einigermaßen zu	Trifft voll zu
Ich finde Lernspiele interessant.	☐	☐	☐	☐	☐
Computerspiele eignen sich gut, um Wissen zu vermitteln.	☐	☐	☐	☐	☐
Ich interessiere mich für Kunstgeschichte	☐	☐	☐	☐	☐
Ich gehe gerne in Museen.	☐	☐	☐	☐	☐

Figure B.9: Pre-questionnaire for the evaluation of ThIATRO

Fragebogen Teil 2A – Europagymnasium Baumgartenberg

1. Bitte zutreffendes ankreuzen

	Trifft überhaupt nicht zu	Trift wenig zu	Unentschlossen	Trifft einigermaßen zu	Trifft voll zu
Ich hatte Spaß beim Spielen von ThIATRO.	☐	☐	☐	☐	☐
Ich fand die Grafik schön.	☐	☐	☐	☐	☐
Ich war mit der Steuerung zufrieden.	☐	☐	☐	☐	☐
Ich habe mich mit der Steuerung schnell zurechtgefunden.	☐	☐	☐	☐	☐
Ich würde das Spiel zuhause noch einmal spielen.	☐	☐	☐	☐	☐
Ich finde, dass die mir vermittelten Informationen wichtig waren.	☐	☐	☐	☐	☐
Ich finde es sinnvoll, Kunstgeschichte anhand von Spielen zu erklären.	☐	☐	☐	☐	☐
Ich fand das Spiel zu schwer.	☐	☐	☐	☐	☐
Die Texte zu Beginn und während der einzelnen Levels waren verständlich.	☐	☐	☐	☐	☐
ThIATRO hat mein Interesse an Kunstgeschickte geweckt.	☐	☐	☐	☐	☐

2. Sonstige Anmerkungen (schreib, soviel du willst):

Besonders gefallen hat mir an ThIATRO...	
Am wenigsten gefallen hat mir...	
Sonstige Anmerkungen	

Figure B.10: Post-questionnaire for the evaluation of ThIATRO, experimental group

Fragebogen Teil 2B – Europagymnasium Baumgartenberg

1. Bitte zutreffendes ankreuzen

	Trifft überhaupt nicht zu	Trift wenig zu	Unentschlossen	Trifft einigermaßen zu	Trifft voll zu
Ich hatte Spaß beim Diskutieren der Bilder.	☐	☐	☐	☐	☐
Mir hat die Gestaltung des Unterrichts gefallen.	☐	☐	☐	☐	☐
Ich werde mich zuhause näher mit Kunstgeschichte beschäftigen.	☐	☐	☐	☐	☐
Ich habe etwas Neues gelernt.	☐	☐	☐	☐	☐
Ich finde es sinnvoll, Kunst anhand von mit Bildbeispielen zu erklären und zu diskutieren.	☐	☐	☐	☐	☐
Die Diskussion hat mein Interesse an Kunstgeschichte geweckt.	☐	☐	☐	☐	☐

Figure B.11: Post-questionnaire for the evaluation of ThIATRO, control group

Participant	Sex	Hours in front of computer a week?	How often playing computer games?	Gaming skills	Playing with...		Learning games are intersting	CGs are a good tool to comm. knowledge	I am interested in art history	I enjoy visiting museums
1	M	1-3	monthly	advanced	PC/Mac		3	4	4	4
2	F	3-5	weekly	advanced	PC/Mac, Console		4	4	4	5
3	F	3-5	never	beginner	-		3	1	4	4
4	M	1-3	monthly	beginner	PC/Mac, Mobile Console		3	4	3	3
5	M	> 5 hours	daily	advanced	PC/Mac, Console, Mobile Console,		5	5	4	4
6	F	3-5	never	beginner	PC/Mac, Console, Card-/Boardgames		4	3	5	5
7	F	3-5	never	beginner	Card-/Boardgames		3	3	5	5
8	F	> 5 hours	never	beginner	Card-/Boardgames		4	4	5	5
9	M	1-3	weekly	advanced	PC/Mac, Mobile Phones		5	4	5	5
10	M	> 5 hours	monthly	beginner	PC/Mac, Console, Mobile Phone		4	4	5	5
11	M	> 5 hours	weekly	advanced	PC/Mac, Console, Card-/Boardgames		4	5	5	5
12	F	1-3	never	beginner	PC/Mac		3	5	5	5
Summary	Male: 6 Female: 6	0-1 hours: 0 1-3 hours: 4 3-5 hours: 4 > 5 hours: 4	never: 5 monthly: 3 weekly: 3 daily: 1 several times/day: 0	beginner: 7 advanced: 5 expert: 0	PC / Mac: 9 Consoles: 5 Mobile Console: 2 Mobile Phone: 2 Card- / Boardgames: 5	Mean	3,75	3,83	4,50	4,58
						SD	0,75	1,11	0,67	0,67

Figure B.12: Results of students' evaluation, pre-questionnaire

Participant	Fun while playing ThIATRO	I liked the graphics	Satisfied with controls	Learned controlling the game quickly	I would play the game at home	Information important?	Useful to teach art history in games?	ThIATRO too difficult?	I read the introductory texts	Sparked interest in art history?
1	4	4	4	4	4	5	5	2	4	4
2	4	3	3	4	5	4	5	1	4	4
3	5	5	2	2	5	5	5	3	5	5
4	5	4	4	4	3	4	4	1	4	4
5	5	4	5	5	4	4	5	1	4	3
6	4	4	4	5	3	4	4	1	4	4
7	4	5	4	5	3	4	5	1	5	3
8	5	5	5	4	5	5	5	1	4	5
9	5	5	5	5	5	5	5	3	3	4
10	5	4	4	4	5	5	5	2	5	5
11	5	4	4	5	5	5	5	1	5	5
12	5	3	5	5	4	5	5	2	4	5

Mean	4,67	4,17	4,08	4,33	4,25	4,58	4,83	1,58	4,25	4,25
SD	0,49	0,72	0,90	0,89	0,87	0,51	0,39	0,79	0,62	0,75

Figure B.13: Results of students' evaluation, post-questionnaire

Participant	Sex	Hours in front of computer a week?	How often playing computer games?	Gaming skills	Playing with...		Learning games are intersting	CGs are a good tool to comm. knowledge	I am interested in art history	I enjoy visiting museums
1	F	1-3	daily	advanced	PC/Mac, Mobile Phone		3	4	2	4
2	F	1-3	several times/day	advanced	PC/Mac, Console, Mobile Console, Mobile Phone		2	3	2	2
3	F	1-3	several times/day	beginner	Mobile Phone		3	3	5	3
4	F	1-3	several times/day	advanced	PC/Mac, Mobile Console, Mobile Phone		4	2	4	3
5	M	1-3	never	beginner	PC/Mac, Card-/Boardgames		4	4	4	4
6	F	1-3	daily	advanced	PC/Mac, Console, Mobile Console, Mobile Phone		3	4	3	4
7	F	1-3	monthly	beginner	PC/Mac, Mobile Phone, Card-/Boardgames		2	2	2	2
8	F	1-3	several times/day	beginner	PC/Mac, Mobile Phone		1	3	1	1
9	F	1-3	several times/day	beginner	PC/Mac, Console, Mobile Phone		3	4	4	4
10	M	0-1	daily	advanced	PC/Mac		3	4	1	2
11	F	1-3	daily	beginner	PC/Mac, Mobile Phone		1	2	2	1
12	M	0-1	daily	expert	PC/Mac, Console, Mobile Console		3	2	4	4
13	F	0-1	never	beginner	Card-/Boardgames		2	4	1	3
14	M	1-3	daily	advanced	PC/Mac, Console, Mobile Phone, Card-/Boardgames		2	4	3	3
15	F	1-3	weekly	beginner	PC/Mac, Mobile Phone		3	4	4	3
16	M	1-3	several times/day	expert	PC/Mac, Console, Mobile Console		3	4	3	3
17	M	0-1	several times/day	expert	Console		4	5	2	1
18	M	0-1	weekly	advanced	PC/Mac, Console, Mobile Console		3	4	2	4
19	M	1-3	several times/day	expert	PC/Mac, Console		3	4	2	1
20	F	1-3	weekly	beginner	PC/Mac, Mobile Console		3	3	2	2
Summary	Male: 8 Female: 12	0-1 hours: 5 1-3 hours: 15 3-5 hours: 0 > 5 hours: 0	never: 2 monthly: 1 weekly: 3 daily: 6 several times/day: 8	beginner: 9 advanced: 7 expert: 4	PC / Mac: 17 Consoles: 10 Mobile Console: 7 Mobile Phone: 11 Card- / Boardgames: 4	Mean	2,75	3,45	2,65	2,7
						SD	0,85	0,89	1,18	1,13

Figure B.14: Results of pupils' evaluation, pre-questionnaire of control and experimental group

Participant	Fun while playing ThIATRO	I liked the graphics	Satisfied with controls	Learned controlling the game quickly	I would play the game at home	Information important?	Useful to teach art history in games?	ThIATRO too difficult?	I read the introductory texts	Sparked interest in art history?
1	4	4	4	4	3	4	4	1	4	4
2	5	4	4	5	4	4	4	2	5	4
3	4	5	5	5	4	4	5	2	5	4
4	5	2	4	4	3	4	5	1	5	2
5	5	3	4	5	4	4	5	1	5	4
6	4	5	4	5	4	4	2	1	4	4
7	5	5	5	5	4	3	4	1	5	3
8	5	5	5	5	4	4	4	1	4	3
9	4	5	5	4	4	3	4	1	5	3
10	5	4	4	5	5	5	5	1	4	4
Mean	4,60	4,20	4,40	4,70	3,90	3,90	4,20	1,20	4,60	3,50
SD	0,52	1,03	0,52	0,48	0,57	0,57	0,92	0,42	0,52	0,71

Figure B.15: Results of pupils' evaluation, post-questionnaire of experimental group

Participant	Fun while discussing the paintings	I like this form of education	I will keep on dealing with art history at home	I learned something new	I think it is useful to discuss art history by means of painting examples	The discussion raised my interest in art history
1	5	5	3	5	5	4
2	4	4	3	4	4	3
3	3	4	2	5	4	2
4	4	5	2	5	5	2
5	4	4	2	5	4	5
6	5	5	3	5	4	4
7	3	3	1	5	4	2
8	4	5	3	5	5	3
9	3	3	1	5	4	2
10	4	3	2	4	4	3
Mean	3,90	4,1	2,2	4,8	4,3	3
SD	0,74	0,88	0,79	0,42	0,48	1,05

Figure B.16: Results of pupils' evaluation, post-questionnaire of control group

Figure B.17: Paintings for tagging before playing ThIATRO. Upper left: Caravaggio, St. Jerome, 1606. Lower left: Fra Angelico, The Annunciation, 1430-1432. Right: Tintoretto, The Stealing of the Dead Body of St. Mark, 1562-1566.

Figure B.18: Paintings for tagging after playing ThIATRO. Upper left: Duccio di Buoninsegna, Annunciation, 1308-1311. Lower left: Ribera, Jusepe de, St. Jerome and the Angel, 1626. Right: Perugino, Pietro, Marriage of the Virgin, 1500-04.

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