The Eduventure -
A New Approach of Digital Game Based Learning Combining Virtual and Mobile Augmented Reality Game Episodes

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Abstract: The availability of mixed reality technologies on mobile computer devices and the high motivational capability of computer games motivated the invention of the Eduventure. The approach combines the idea of digital game based learning with the usage of new mixed reality technologies in a pedagogically reflected way. Thus it has got a unique dual mode structure, which combines virtual and real life game episodes in a synergy as blended learning. Learning is esteemed as a person's active knowledge acquirement, either acting in a virtual environment or as a mobile learner in situ, supported by Augmented Reality (AR). Thereby a major problem of digital game based learning is addressed: the learning transfer. The foundation and evaluation of the Eduventure approach is subject of the interdisciplinary Middle-Rhine Eduventure Project, which is introduced as a case study. Furthermore, this article deals with the issue of special pedagogical relevance of mobile AR for game based learning.

1 Motivation

Computer and video games have become a common leisure activity for children up to young adults and are part of the youth culture [Gr99], [AB01], [Vo03]. This actually encouraged attempts to use computer games in educational contexts, and the issue of digital game based learning [Pr01] has become popular within the scientific discussion on computer based learning. From a pedagogical perspective, the issue needs to be raised whether it is possible to utilize the motivation and engagement effected by computer and video games for learning, and how this can be done best.

"With the recent advances in mobile networking, context-aware computing, and sensor-based computing, researchers and game designers are able to explore the potential of combining these new technologies to develop mobile, context-aware, augmented reality multiplayer games." [Wu04].

2 The Eduventure Approach

The Eduventure approach combines the idea of game based learning with the usage of new mixed reality technology as a blended learning scenario in a pedagogically reflected way. Thus it addresses a major problem of (digital) game based learning, the learning transfer.

2.1 The Problem of Learning Transfer

Some authors doubt the possibility to utilize playing as an instructional mean for learning [Fr93]. It is argued that play is consciously not tied to any learning intentions. Moreover it aims on creating the player's own structures, instead of reproducing externally given ones [Pi62]. Although Prensky [Pr01] is convinced that "it is possible to get learners of all ages totally involved in learning any subject matter" by using computer games, instructional learning by games can not be taken as granted. This objection refers on research results of different science areas: learning theory and epistemology, theory of play and media research.

1) Learning Theory and Epistemology. From a constructivist point of view, knowledge is understood to be formed by the learner himself.. Every person builds his construction of reality on his very own impressions, which are interpreted on the actual subjective construction of reality and embedded in the already existing construction during the learning process [Si03], [AS03]. This building and embedding process does not follow the principles of ontological truth, but viability, which means: it has to be useful and relevant for reaching the learner's goals. With regard to theory of play and media research, this raises the important issue, if and how information embedded particular in computer games could appear relevant and useful to the learner for his real life.

2) Theory of Play. One of the most important approaches of describing the essence of play has been created by Scheuerl [Sc91] by analysing the most relevant contributions to theory of play, and extracting their commonalities. Among others, he identified the following entities of play: (1) Play is independent from any external purposes and consequences of the real world; (2) play takes place in a mental pseudo-world with its own laws, detached from reality. Piaget [Pi62], who developed a theory of play within his epistemology, described play as every mental act with an overweight of assimilation, which means subjecting reality to the player's thoughts). Fritz [Fr93] reasons: play in its real essence is free from any external purposes, and so games aiming on learning goals can not be considered to be real "play". Play takes place in an alternate reality. During play, the player encounters and produces possibilities of reality, not the reality itself. In conclusion it is improbable that a player automatically transfers contents of a game into

his understanding of the real world. Nevertheless, in Brian Sutton Smith's [Su78] - opinion, play increases the repertoire of behaviour by developing cognitive schemes for certain situations the player may sometimes encounter in reality.

3) Media Research. The rules of a virtual world have to be considered very restrictive. Resulting from the immense modelling and technical costs, causality and environment are limited to a small amount of laws and rules - apart from the fact that most computer and video games take place in fictional settings. Fritz created a model for transfers between different worlds (as medial world. virtual world, real world) based on a constructivist point of view. Empirical research [EW97] referring on this model proved that transfer of schemes (including knowledge transfer) between different worlds does not occur offhand. Transfer processes are rather subjected to an inspection of their adequateness, and even if considered to be adequate, virtual impressions underlie a more or less heavy transformation.

What does this all imply for digital game based learning? Virtual gaming experiences remain in a virtual game world. If they are meant to be built into the knowledge concerning the real world, they will have to be proven as relevant and useful information for the individual construction of meaning and understanding of the real world AND to be adequate for usage in the real world.

2.2 Pedagogical Assumptions

Eduventure is a didactical approach, which mixes aspects of a role-based "Adventure" game with "Education" and tries to utilize the motivational capability of computer games. Thereby, "learning" is considered as active knowledge construction, which stresses the aspects of self-guidance, motivation, context and interactivity. Thus the Eduventure approach concentrates on offering multiple occasions for the self-guided and situated learning of the player. *Self-Guidance* is supported, as activity is engaged by inducing intrinsic motivation of the person to voluntarily play the game and to work on the inherent tasks of the game play. Besides, intrinsic motivation is a relevant prerequisite for elaborated learning processes [FM97]. Learning depends on the context and therefore is *situated*. Eduventure stresses realistic and authentic contexts [CBN89], which are relevant for the learner and the domain of learning. Knowledge and cognitive schemes constructed in the "game world" are considered to remain passive and not applicable since they have not proven to be relevant and useful for the solving of problems in the real world..

Unlike others, the Eduventure approach uses the extended possibilities of a *hybrid game design* in a pedagogically reflected way. Thus it has got a unique dual mode structure (fig. 2), which combines virtual and real life game episodes in a synergy as blended learning. The game episodes in presence mode take place in situ, in the existing real world counterpart of the virtual game environment, supported by mobile augmented reality. For successful knowledge transfer, it is important that the cognitive schemes developed in the virtual game episode are activated and their application on real world problems is stimulated. By commonalities of the virtual and real context, cognitive schemes constructed by the player in the virtual game world should be activated and

their application on problems in the real world should be stimulated. The dual mode structure of the Eduventure aims on this knowledge transfer, which is additionally supported by the use of mobile Augmented Reality technology. As learning is problem oriented and driven by tasks in the game the credibility of the entire game play is important for the player's rating of the relevance of the tasks and the information he deals with. High credibility encourages the player to use knowledge acquired during the virtual episode by applying it on the tasks given in the augmented episode in the real world.

In the *virtual game episode,* the learner plays a conventional role based adventure computer game. Concerning the contents, the authenticity and the historical correctness of the game setting is stressed. The player fulfils his mission within a realistic virtual representation of the historical site in a given historical period. Cognitive schemes can be developed and applied in the game environment. The virtual game episode offers only a preliminary ending which is not fully satisfying to the player. The final solution of the mission requires playing the augmented game episode as well. The *augmented game episode* takes place in presence mode at the historical site as a computer supported paper chase. The preliminary ending of the virtual game is picked up and the existing task should finally be solved by the player. To solve the given task, the player has to re-activate his cognitive schemes and knowledge constructions built up whilst playing the virtual episode, verifying their adequateness for applying in the real world. Augmented Reality Technology provides the visual representations of both the site and the plot of the virtual episode at the original historical site.

Figure 1: The Marksburg castle in real life and the virtual game episode

3. Case Study: The Middle Rhine Eduventure Project

The foundation and evaluation of the Eduventure approach is subject of the Middle-Rhine Eduventure Project [Fe05]. A prototype of the Eduventure has been implemented and tested as a proof-of-concept by the example of the Middle Rhine Eduventure. The project especially deals with the question of the pedagogical impact of Augmented and Virtual Reality to foster learning as active knowledge acquirement of mobile persons,

acting either in situ, i.e. in an existing (augmented) historical site, or in a virtual environment. Thus computer scientists and pedagogues interdisciplinary work together in the project. The game play is located at the Marksburg (fig. 2), a medieval castle from the 12th century in the UNESCO cultural heritage Middle-Rhine valley in Germany. From content perspective, the project aims on the cultural history of the Middle-Rhine valley, with a special focus on the Marksburg castle.

3.1 Story and Game Structure of the Middle Rhine Eduventure

David Siegel analysed the story structure of many movies and found out that the most successful movies have got what he calls a "Two-Goal Structure": "This involves the protagonist striving for the false goal, then learning something that changes the whole situation and going for the real goal to save the day in the end" [Si]. The Middle Rhine Eduventure uses this structure in order to achieve an interesting and exciting plot.

1) Story. Two scientists invented a time machine. Unfortunately, their doddery charwoman accidentally got lost somewhere in the past, taking the remote control needed to get her back with her. The scientists only know that he charwoman must have reached the Marksburg castle in the time of the Thirty Years War in Europe. Therefore the player is charged with the rescue of the charwoman, and he should tell her how to use the remote control in order to get back. Without a remote control, he relies on the scientists to take him back to the presence, using a PDA for trans-time communication with them. Arriving in the past, he accidentally loses his PDA and finds himself alone in the past, where the charwoman is still lost. His objective is to find the PDA and the charwoman. After some quests, searches and tasks, he finally finds her. Just before he is taken back to the presence by the scientists, the charwoman interjects she has already been in the past for several years, having thrown away the remote control some time ago. Back in the presence, the scientists and the player notice that the time machine is unable to allow a third travel in the past. As a solution they decide to visit the Marksburg castle in the presence with a less powerful computer device, which only allows the player to look into the past and to project a hologram of the player, allowing conversations with the people in the past. The player finds out the exact location and time of the arrival of the charwoman and tells her how to use the remote control in order to get her back.

2) Game Structure. A prologue introduces the story of the game. For the prototype it only consists of a short pre-rendered video sequence. For the further development of the Middle Rhine Eduventure, an augmented prologue with a mobile device at the Marksburg castle is intended as an alternative entry point in the game, especially for visitors of the castle. The following virtual episode alternates with in situ real world episodes at the historical site in the Middle-Rhine valley, which are partly augmented and technologically supported by AR and mobile, context-aware computing.

The virtual episode (Eduventure part 1) consists of a role based adventure game with a preliminary ending. The first part of the story takes place in this episode and starts after the prologue. It includes the time travel to the Marksburg and the finding that the first goal was misleading and the mission had failed. The second part of the story is dedicated

to the second goal and includes the search with the less powerful computer device as an augmented paper chase at the Marksburg castle (Eduventure part 2).
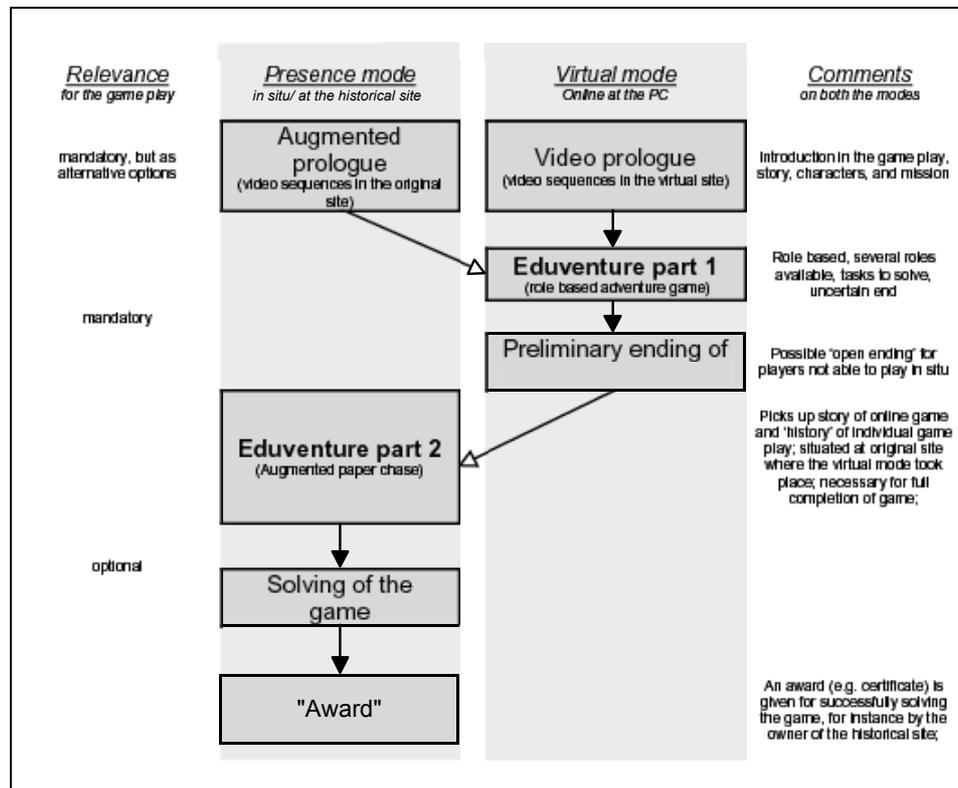

Figure 2: The dual mode structure of the eduventure

Though being different game types, the two episodes are strongly connected by their common and mutual storyline. One single part does not make the entire game experience, but joined together they should lead to an innovative game experience and the intended learning processes. Situated information and impressions acquired in the virtual episode are picked up by the story and "bridged" to the real world episode, where its relevance and usefulness for the solution of problems can be proofed and thus knowledge transfer can be stimulated.

3.2 Technical Aspects

For the implementation of the prototype an existing game engine (see below), which can legally be modified, is used to model the role based adventure game of the virtual episode. The virtual world consists of a specially designed and realistic 3D model of the Marksburg castle for the authentic context of the game. Interaction in the game is prevailingly realized via dialogues, where the engine offers suitable possibilities. For the

augmented game episode, non-stationary markers, which are put up at certain locations, are being used.

1) Virtual Episode. The virtual episode is realized as a modification of a commercial computer game, called "Gothic" [Go00]. Most of the features that are required by the plot are already implemented and can be combined through a scripting language. Such features include: display of static world geometry, rendering and animation of NPCs ("none player characters") and the PC ("player character"), display of dialogs, and story-Logic, state and a scoring system.

Creation of a mod involves two main tasks: modelling of custom settings/ objects and scripting. The *modelling* is realized by importing industry standard 3d scenes from an extern modelling package such Autodesk 3ds max. In order to use the Marksburg as a virtual setting, a virtual copy was produced. The geometry consists of around five thousand faces, which meet the requirements for interactive use, like efficiency for real time display and consistence for collisions detection. Although the geometry remained mostly the same

Figure 3: A dialog with an NPC

throughout the centuries [BD93], the textures did change substantially. Therefore they were painted by hand for a small subset of the geometry, already offering promising results. It was also possible to closely model the surrounding Rhine valley by panoramic environment maps that can be used with Gothic after some tweaking. The *scripting* uses a somewhat restricted proprietary scripting language that comes with Gothic. Four classes of scripts are required: NPCs, items, dialogs and behaviours (fig. 3). The dialogs drive the story, also offering additional information about the castle and its history. Gothic's default behaviours also required modification, as they are sometimes too aggressive and action-oriented.

Gothic has been created in the late 90ies with the first or second generation of hardware-accelerated graphic chips as a target. It's not possible to achieve the level of graphical detail presented in state of the art games under these conditions.

2) Augmented Episode. The augmented episode of the Eduventure takes place at the Marksburg castle as some kind of "augmented reality paper chase". The player is supposed to move trough the castle, along a series of checkpoints, in order to reach the final goal of the game: finding the charwoman and telling her how to get back. To support mobility during game play, for game output a Tablet-PC with an attached USB webcam is used. In the Eduventure, the ARToolkitPlus [Wa05] software library is the basis for

augmenting reality, using id-based markers to identify the respective checkpoints. At each of these stages the user watches and interacts with the game (fig. 4). Because of the limited time due to the regular guided tours and the less space, the dialogs within the game are quite linear to concentrate the player's actions on several areas of the medieval castle. This is not considered as a disadvantage (like the linearity of certain computer games sometimes are rated low), because the main task in the augmented episode is to find the next "AR checkpoint" by the information gathered from the previous one and by the re-activation of the knowledge built during the VR-part. The storyline and tasks are scripted in an XML file, which also stores configurational data like e.g. light settings. Therefore it is possible to meet different light conditions in a flexible and easy-to-adjust way. Dialogs and tasks are easy to edit and do not require the software to be re-compiled as it would be in a hard-coded configuration.

Figure 4: The player is looking at a checkpoint during the augmented episode of the Eduventure

4. Relevance of mobile AR

What is the didactical potential of mixed reality technologies for game based learning, and where can especially mobile AR contribute? There are arguments for the benefit of *AR-technology* for games like the real world becomes part of the game, better immersion or intuitive interaction. However, the breakthrough of AR-games is still missing and a 3D game with a virtual environment is still the best and most convincing choice for the broad audience, since the real benefits and potentials of AR seem to be not enough evaluated and thus not efficiently exploited. In a more educational sense there had been several attempts to provide an added value to traditional information visualisation with *VR technology* (3D web, 3D information visualisation) – without mayor acceptance. However, VR proofed its potential for the user to experience things, that do not (yet) exist (e.g. virtual prototyping), that do not exist anymore (e.g. virtual cultural heritage) or are unreachable in reality (e.g. cosmos, history). It has proofed to use methods of "digital storytelling", where the information is provided in an interactive story, rather than in a linear manner. Combined with AR-technologies, the same concepts can be applied for mobile scenarios, especially for tourists at cultural sites. A very good example is the ARCHEOGUIDE system as an AR guide for tourists at the historic Olympia [Vl02].

The Eduventure approach combines the benefits of both VR and AR technologies in a hybrid game-based learning scenario. Thus we gain an added value for learning and contribute to exploit the didactical potential of the new technologies. It provides a complex and authentic learning context both in the virtual and the augmented game episode,

Figure 5: The same checkpoint as shown in figure 4, as it appears in an AR view on the tablet PC

which is a major issue for the initiation of situated learning and learning transfer and is supported by mixed reality technologies.. Commonalities of the virtual game world and the real world foster the activation of cognitive schemes developed in the virtual game episode and their application on real world problems. Mobility is a crucial aspect for the augmented game episode. Mobile devices allow supplying realistic ambience information to create immersive experiences and to offer more intuitive ways of interaction by merging real and virtual environments. These aspects increase the credibility of the entire game setting. Credibility of both contexts and tasks is important for the player's rating of their relevance and his motivation to understand and deal with the information offered in the game. High credibility encourages the player to apply prior knowledge from the virtual episode on the tasks in the augmented episode in the real world.

AR mainly is supposed to support transfer of cognitive schemes from the virtual into the real world by providing visual representations of both the site and the plot of the virtual episode at the original historical site, thereby giving occasions for proving their adequateness regarding the real situation.

5. Outlook

The Eduventure approach has been worked out and exemplarily tested in the Middle Rhine Eduventure project in 2004/2005. The Eduventure approach and the didactical potential of VR and mobile AR technology are being focussed by the evaluation. Of particular interest are possible transfer processes: Does the Eduventure as a blended game based learning approach facilitate learning transfer between playing in a virtual world and knowledge construction in the real world?

In August 2005 there was a test run of the AR-part with some students, which was preceded by a test phase of the VR-part. Subsequent to this, there was an evaluation realised by interviews with the participants (fig. 6). At the moment, those interviews are being gathered and interpreted. The following aspects are of major relevance for the evaluation:

- *Motivational aspects:* Did the player enjoy the story? Did the game (particularly the virtual part) appear as a game 'for fun" or was it experienced to be more like instruction?
- *Credibility/ authenticity:* Did the virtual part of the game seem credible? Or did it rather seem like a fictional, unrealistic scenario?
- *Learning transfer/ situated learning:* Did the cognitive schemes the player developed during virtual gaming apply to problem solving in the augmented situation? Did the AR-part increase the credibility of the virtually presented contents?
- *Self guided/ mobile learning:* Was it possible to "explore" the castle Marksburg in an individual manner? Did the mobility of the AR part support learning and knowledge transfer?
- *Learning results:* Did the player learn something about the Marksburg and the history of the 30 years war in Germany?

The Middle Rhine Eduventure is just a pilot project and intended as a starting point for a more detailed and elaborated future development of the Eduventure. The work necessary for the conceptual and story design and implementation of such an extended project requires recognizable financial effort. The parallel focus on tourists as a target audience of the Middle Rhine Eduventure might allow a commercial usage of the project and financially support the further developments.

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