GAME-BASED LEARNING
Conceptual Methodology for Creating Educational Games

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Abstract: Game-based learning builds upon the idea of using the enjoyment and the motivational potential of video games in the educational context. Thus, the design of educational games has to address optimizing enjoyment as well as optimizing learning. Within the EC-project ELEKTRA a methodology about the conceptual design of digital learning games was developed. Thereby state-of-the-art psycho-pedagogical approaches (like the Competence-based Knowledge Space Theory) were combined with insights of media-psychology (e.g., on parasocial interaction) as well as with best-practice game design. This science-based interdisciplinary approach was enriched by enclosed empirical research to answer open questions on educational game-design. Additionally, several evaluation-cycles were implemented to achieve further improvements. The psycho-pedagogical core of the methodology can be summarized by the ELEKTRA's 4Ms: Macroadaptivity, Microadaptivity, Metacognition and Motivation. The conceptual framework of the developed methodology is structured in eight phases which have several interconnections and feedback-cycles that enable a close interdisciplinary collaboration between game design, pedagogy, cognitive science and media psychology.

1 INTRODUCTION

Game-based learning is a relatively new research area and so far there exist no concrete systematic recommendations for the conceptualization of an integrated design of educational games.

In the following, a newly developed conceptual framework for the creation of educational (adventure-)games will be outlined and illustrated by several concrete examples and empirical (evaluation) studies. The proposed methodology was developed and successfully used in the EC-project ELEKTRA (*E*nhanced *L*earning *E*xperience and *K*nowledge *Tra*nsfer). The described process can serve as a model for other contexts of game based-learning as well as the creation of serious games.

1.1 Game-based Learning

Game-based learning is a kind of edutainment that rests upon the idea of using the motivational and immersive potential of conventional video games in the educational context. Even though there are several publications on games, game-play (Salen &

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Zimmermann, 2004) and game-based learning (Prensky, 2005), the divers contributions are often rather unconnected and an overall framework for the creation of educational games is still missing.

The main problem in this context is the seldom collaboration between psycho-pedagogical scientist and industrial game designers. For an appropriate serious game design, both, the creativity of game designers as well as the expertise of psycho-pedagogical scientists are necessary.

A first step in this direction was made within the EC-project ELEKTRA which will be described in the next subchapter.

1.2 EC-project ELEKTRA

ELEKTRA (*E*nhanced *L*earning *E*xperience and *K*nowledge *Tra*nsfer) was an EC-project under FP6 on game-based learning. The aim of the interdisciplinary research project was twofold: On the one hand it aimed at the development of a state-of-the-art educational adventure-game to make learning as exciting as leading-edge computer games. For this practical aim the so-called ELEKTRA-demonstrator was developed which comprises the first chapter of an educational adventure-game on the learning domain physics/optics. On the other hand a general methodology about the conceptual design and production of digital learning games should be established. This second aim was accomplished by the ELEKTRA methodology which will be described in this article.

The core idea of producing effective and motivating digital game-based e-learning experiences for young children relies on an interdisciplinary approach which combines state-of-the-art research in cognitive science, pedagogical theory and neuroscience with best industrial practice in computer game design.

The developed methodology builds not only a framework for structuring and supporting the interdisciplinary cooperation, but also inherent several interrelated phases and evaluation-cycles that enable continuous improvements and enhancements of the educational game design.

1.3 The ELEKTRA Methodology: Overview

On a general level, the ELEKTRA methodology does not re-invent the wheel but shares a lot of elements with usual instructional design models that many readers might be familiar with (e.g., Brown & Green, 2006). In particular the proposed methodology can be seen as an adaption of the Dick and Carey System Approach Model (Dick, Carey & Carey, 2005) – revised for the purpose of making a state-of-the-art digital learning game.

The base of the developed methodology can be summarized by the ELEKTRA's 4Ms: *M*acroadaptivity, *M*icroadaptivity, *M*etacognition, and *M*otivation. Within the ELEKTRA-project we identified these 4Ms as the pivotal elements of an (exciting) educational game (independent of the concrete learning content and storyline/genre of the game). In order to manage the workflow within the interdisciplinary collaboration a framework with eight phases was developed:

- Phase 1: Identify instructional goals
- Phase 2: Instructional analysis
- Phase 3: Analyse learners and context of learning
- Phase 4: Write performance objectives and overall structure of the game
- Phase 5: Learning game design
- Phase 6: Production and development
- Phase 7: Evaluation of learning
- Phase 8: Revise instruction

Even though these phases are numbered from one to eight, they do not follow a linear order but have several interconnections and feedback cycles. Figure 1 illustrates the workflow within the eight phases of the model.

The ELEKTRA's 4Ms are mainly addressed in phase 5 which can be suggested as the core of the methodology: the learning game design. But also the other phases relate to the 4Ms in an implicit way: The phases before feed in the learning game design, the succeeding phases rely on the learning game design and its implementation and improvements, respectively.

In the following, first the ELEKTRA's 4Ms will be characterized. Second, the eight phases will be described; thereby the focus lies on the psychological contribution within this framework. Several practical and empirical examples from the ELEKTRA-project will be given. Finally, a short resume will be provided.

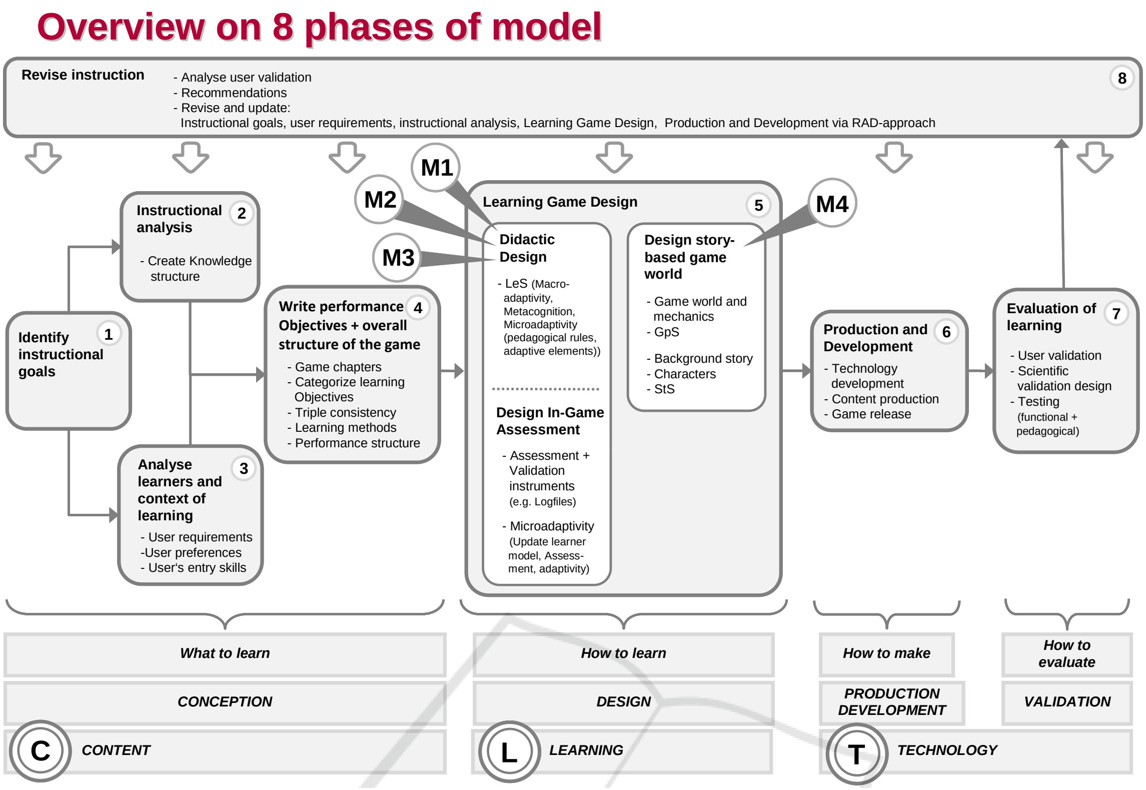

Figure 1: Overview on eight phases of the model.

2 ELEKTRA'S 4MS

The ELEKTRA's 4Ms include the pivotal features of a successful educational game. The headwords Macroadaptivity, Microadaptivity, Metacognition, and Motivation are only rough catch phrases for various elaborated concepts, models and findings. Within the ELEKTRA project the main psychological contributions regard to microadaptivity and motivation. The work on macroadaptivity and metacognition was mainly part of the pedagogical partners.

2.1 M1 - Macroadaptivity

Macroadaptivity deals with the adaptive pedagogical sequencing of alternative learning situations for one learning objective. Thereby macroadaptivity refers to the instructional design and management of the available learning situation. It addresses the adaptivity between different learning situations and refers also to a diversification of learning based on Bloom's taxonomy (1956).

The macroadaptive process leads to the creation of a learning path which represents a specific combination of divers learning situations.

2.2 M2 - Microadaptivity

Microadaptivity regards to adaptive interventions within a learning situation. It involves a detailed understanding of the learner's skills and a set of pedagogical rules that determine the interventions given to the learner. Within ELEKTRA the idea behind the concept of microadaptivity (Albert, Hockemeyer, Kickmeier-Rust, Pierce, & Conlan, 2007) is to develop a system that provides hints adapted on the user's (current) knowledge and competence state. Whereas macroadaptivity refers to traditional techniques of adaptation such as adaptive presentation and adaptive navigation on the level of different learning situations microadaptivity deals with the adaptivity *within* a single learning situation.

The basis of the microadaptive skill assessment and the non-invasive interventions is a formal model for interpreting a learner's (problem solving) behavior. To realize the non-invasive skill-assessment and the adaptive interventions, ELEKTRA relies on the formal framework of the Competence-based Knowledge Space Theory (CbKST; Albert & Lukas, 1999; Doignon & Falmagne, 1999; Korossy, 1997). Originating from conventional adaptive and personalized tutoring, this set-theoretic framework allows assumptions about the structure of skills of a domain of knowledge and to link the latent skills with the observable behavior. Microadaptivity in this context means that the intervention/hint was selected on the basis of knowledge assessment via CbKST. The chosen hint provides either the necessary information to solve the problem (to learn a missing skill) or the affective support (e.g., motivating or activating feedback) fitting the current progress state of the learner assessed by his action history.

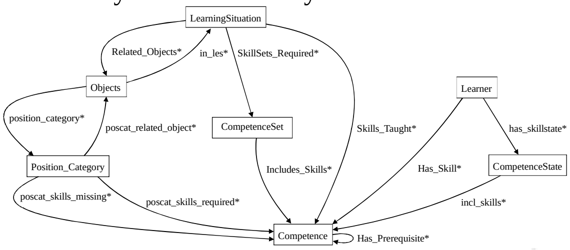

Figure 2: Microadaptivity – integrated model.

Within the ELKTRA-demonstrator the microadaptive interventions were presented by a non-player character (NPC) named Galileo in order to merge microadaptivity with the storyline and the overall game play.

Figure 3: Using the non-player character named Galileo for providing microadaptive interventions.

2.3 M3 - Metacognition

Regarding Flavell (1976, p. 232) "Metacognition refers to ones knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data". Even though there exists slightly different interpretations of this original definition, metacognition is agreed to involve knowledge about one's own knowledge as well as knowledge about one's own cognitive processes. The ability of the ELEKTRA-demonstrator to foster metacognitive development was considered as a major challenge and an important differentiator compared to traditional educational games.

The integration of a reflective pause in the game-based learning process seems at first sight contradicted to storytelling and the flow of game play. Within ELEKTRA the resolution to this dilemma is based on two pillars: First, the implementation of certitude degrees, i.e., while performing a task, the learner has to indicate the prudence and confidence he has in his performance. Second, a firm support of this kind of metacognition by the storytelling, i.e., the prudence and confidence estimation were made in a close parasocial dialog with the NPC Galileo.

The metacognitive reflections therefore are tightly bound to the gaming process. Thereby the ELEKTRA-demonstrator contributes to develop not only the ability to perform, but also to understand the conditions of success, and thus, having cognitive and sometimes metacognitive goals in addition to the pure performing goal.

2.4 M4 - Motivation

The fourth M named *M*otivation comprises several motivational concepts and related approaches used for enjoyment and learning. Motivation in this sense is only a keyword for different aspects of the storyline, the challenges and skills (flow-experience), the intrinsic motivation of the gamer, the parasocial interaction and empathy with the NPCs as well as the identification with the avatar.

In general, motivation is a phrase used to refer to the reason(s) for engaging in certain activities. In the context of learning games, the creation of motivation to engage in and perform learning activities is a core element of good game design and can be suggested as the major advantage of educational games compared to other ways of e-learning.

There are many aspects of games which are suggested to contribute to the gamers motivation (Vorderer & Bryant, 2006), e.g., competition, parasocial interaction with the NPCs fantasy, escapism, suspense or curiosity as well as the balance between challenges and skills (enabled by different game-levels) which in turn fosters the so-called flow-experience (Csikszentmihalyi, 1990). Within ELEKTRA we mainly focussed on the storyline and the game characters as motivational tools for learning. This includes the creation of a story that adds "sense" to specific learning activities, i.e., the learning activities are an integrative part of the story itself. Thereby the story confronts the player with certain game-challenges/problems (e.g., riddles) that he can only solve when he first learns certain skills and the story makes it worth to do so.

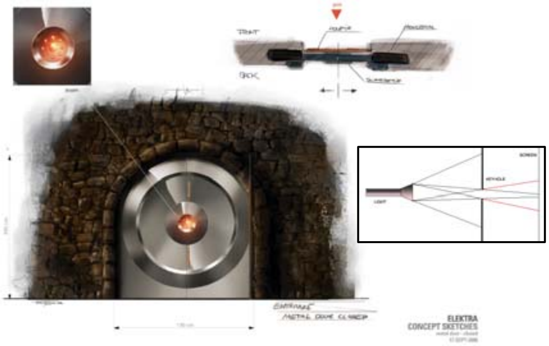

Figure 4: Riddle within the ELEKTRA-demonstrator: Solution requires knowledge on optics.

A typical example would be that the learning activities influence the fate of the avatar or the good and bad NPCs. The crucial thing is to merge learning activities and storyline in a playful way.

The usage of the storyline (including game-characters) as a motivational tool comprises several subtasks: designing a setting, a general plot, interesting good and bad characters with which the players can have an immersive parasocial interaction and an avatar with which the players can easily identify.

3 DESCRIPTION OF THE EIGHT PHASES

In the following the eight phases will be described. Like mentioned above it is important to note, that these phases don’t follow a simple linear order but rather comprise several interconnections and feedback cycles (see also figure 1).

The psycho-pedagogical contributions within ELEKTRA regarded mainly to the phases of instructional analysis, the analysis of the learners and the context of learning, the learning game design and the evaluation phase. For these phases concrete practical and empirical examples will be given to illustrate the important part of cognitive science and media psychology in the conception of educational games.

3.1 Phase 1: Identify Instructional Goals

In this early stage, pedagogy clearly prevails the overall game design by setting some fundamental pedagogical and didactical decisions with respect to the chosen learning goals, the basic areas of learning content and the general pedagogical approach. The context of the game has to be outlined as well: Should the learning game be deployed in a class-room situation at school or should it be played at home as a spare-time activity? This decision is another important cornerstone for the general conditions of the whole design of the learning game.

After the definition of learning goals, topic, target group, learning content, pedagogical approach and the context, the general framework of the game is settled. This pedagogical framework not only constitutes the learning experience in the game, but also has got a fundamental impact on the overall concept of the game design. The choice of the game genre is the first crucial design decision which is directly dependent on the learning objectives. If you like to create for example a strategic simulation game, you would perhaps choose different types of learning goals than for a racing game.

3.2 Phase 2: Instructional Analysis

In phase 2 the learning objectives and the related learning content are transferred into a formal knowledge structure which is called knowledge space. The theoretical background and mathematical-formal framework is delivered by the already mentioned CbKST. In this context, the main advantage of the CbKST is the clear distinction between observable behaviour and the underlying skills and their interrelationships. Thereby the prerequisite relations between skills as well as between behaviours enable the adaptation to the actual available skills of the learner as well as the adaptation to the ongoing learning progress.

In the established knowledge space all of the learning objectives are represented as an ontology of skills. Thereby the accordingly skills are structured as a map that allows analyzing the developing knowledge state of the learner and thus a learner model. In addition, it allows adapting the game environment to the individual learning needs of the player. This can take place on different levels, e.g., on the level of macroadaptivity or on the level of microadaptivity.

3.3 Phase 3: Analyse Learners and Context of Learning

Phase 3 contributes to the detailed analysis of the learners and the context of learning. Thereby the characteristics of the learner group concerning entry skills, learning problems, preferences and attitudes are determined. In a learning game, these areas refer to the learning process as well as to the game play (Linek, 2007). Thereby the twofold role of the target user has to be taken into account: he is both, a learner and a player.

Entry skills for the *learner* could be known difficulties in the chosen learning topic. Additional, entry skills for the *player* could be the state of his game literacy.

The learner analysis serves as input for a variety of game decisions: For example the NPC design, the visual style of the game, and the provision of specific learning methods. It is also used to determine the initial state of the learner model. These decisions could be partly made by help of existing literature and research findings. However, with respect to the concrete game design partly additional empirical studies might be necessary.

For example within the ELEKTRA-project a focussed multimedia study on the NPC-design (regarding his friendliness, the naturalism of the graphics and the role of color) was conducted.

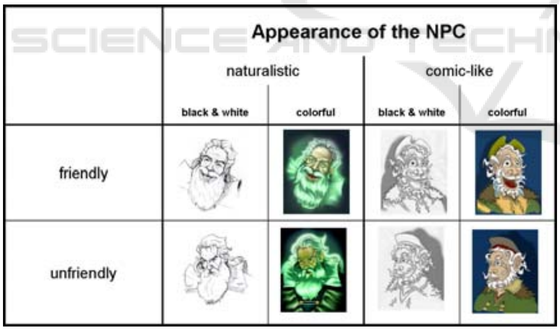

Figure 5: Experimental design of the so-called NPC-study.

The results of this so-called NPC-study indicate a clear preference for a colored, naturalistic NPC-design. For the NPC's friendliness the pupils favor a NPC that was similar to their own, indicating similarity-attraction (Linek, Schwarz, Hirschberg, Kickmeier-Rust, & Albert, 2007).

3.4 Phase 4: Write Performance Objective and Overall Structure of the Game

On the basis of phases 1 to 3, performance objectives are laid out and, closely linked to this, the overall pedagogical structure of the game is written. This basic scenario is a kind of working paper which will go through various changes throughout the continuing revising process of the creation for the game.

In particular the overall pedagogical structure should include a general description of the *story* of the game (including the setting, the characters, and the plot), the *game-chapters* as well as various *situations* of the game that build up the chapters. They are described in a rough way which mainly includes their main functionality within the game and their possible sequences which can include adaptive branches.

3.5 Phase 5: Learning Game Design

Phase 5 is the very core of the ELEKTRA methodology and the accordingly design of a learning game. It is the central work phase where the successful integration of learning and gaming takes place and everything comes together. The main task in this phase is to develop detailed descriptions of each situation in the game: Learning situations (LeS), gameplay situations (GpS), and storytelling situations (StS). Every situation must be described in terms of stage, possible actions, and events that happen in the environment in reaction to the player's activities. The output is a "Game Design Document" which gives programmers (development) and artists (content production) precise instructions for the development and production of the educational game.

The challenge of this design process is to design those three types of situations in such a manner that they constitute pedagogical valid learning activities that are embedded in a meaningful and exiting learning game experience for the player.

In an ideal learning game experience the three essential situation types work together as ingredients of a new experience which would arrange a superior game situation from games, learning, and storytelling. This ideal is not always achievable but at least the gameplay situations, learning situations and storytelling situations should motivate, amplify and legitimate each other by embedding them into a meaningful context.

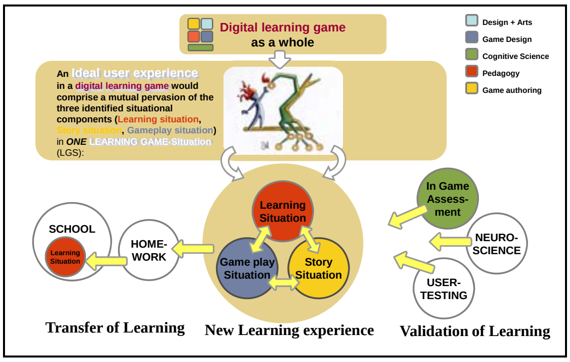

Figure 6: The ideal learning game situation.

The conceptual tools for the design of the situations and their sequencing are based on the already described ELEKTRA's 4Ms. Thereby *M*acroadaptivity, *M*icroadaptivity, and *M*etacognition are mainly concepts of the instructional strategy of the learning situations and the appending in-game assessments, while *M*otivation is rather the objective of the story-based game world.

3.6 Phase 6: Production and Development

There are two main work areas in the production and development phase: On the one hand programmers develop the various technologies required for the game, on the other hand, artists and producers create all the media assets that are necessary to build the game world. Roughly spoken, one can say, that the development team works on the logic of the game while the production team creates the data for it.

The necessary input for the development team and the content production team are the pedagogical scenarios written in phase 4 and the Game Design Document of phase 5. During phase 6 there is a vivid exchange between the programmers of the development team and the artists and producers of the content production team.

The outcome of this phase is a published release version of the game that can be tested, played and evaluated.

3.7 Phase 7: Evaluation of Learning

There are two different forms of evaluation: the formative evaluation and the summative evaluation of the game.

The formative evaluation is called testing and is closely connected with the development and production work in phase 6. Ideally, the formative evaluation should take place in (monthly) timeboxes when a new testable version of the game-prototype with the latest implementations and improvements is delivered (as output of phase 6). This iterative timebox releases will undergo each time a functional and psycho-pedagogical testing. The formative evaluation can concentrate on single game-elements like background-music or game characters or might deal with the implementation of a new approach like microadaptivity in ELEKTRA (Linek, Marte, & Albert, 2008). The evaluation results of this testing will directly feed back into early phases.

Thereby, the report on technical testing describes functional bugs that manifest themselves in mistakes of the game system. The programmers then have to correct or change the according software components. The report of the psycho-pedagogical testing relates to gaming and learning experiences of the target end user. The results of the psycho-pedagogical evaluation forces sometimes even to go back to the design phase (5).

The summative evaluation can be described as a general evaluation of the developed game and the whole process. It takes place when the iterative technical testing leads to a stable running and psycho-pedagogical meaningful version of the game. In order to analyse the learning behavior and success of the pupils in the game and their evaluation of the gaming experience as a whole, a science-based methodology is applied, using standardized questionnaires as well as logfile-information. In this context not only control variables and pre-questionnaires are considered, but also long-term effects of the learning-game experience should be assessed (e.g., to assess the long-term knowledge gain).

3.8 Phase 8: Revise Instructions

Subsequent to the game testing and the empirical summative evaluation, the next essential step is to interpret and exploit the evaluation results for providing recommendations for improvements and enhancements of the learning game as a whole.

These recommendations have to be feed in all preceding phases, affecting all previous tasks and activities and hence, might resulting in a revision and update of the instructional goals (phase 1), instructional analysis (phase 2), user requirements and preferences (phase 3), learning game design (phase 5) as well as production and development (phase 6).

Moreover, also the implementation of the evaluation itself might befall revision, e.g., in case of an emerging need for improving the assessment instruments / questionnaires. This in turn requires a close collaboration between scientific research and evaluation. Accordingly, research partners are responsible for selecting scientific sound evaluation instruments as well as for proposing an adequate methodology and data-analysis.

4 CONCLUSIONS

The proposed methodology delivered a general conceptual framework for the creation of a broad spectrum of educational games. The applicability and validity of the methodology was firstly proven within the ELEKTRA-project. The ELEKTRA-demonstrator was evaluated empirically and proved its effectiveness for enjoyment as well as for learning. Besides this first positive evidence of the effectiveness of the proposed methodology, also the newly developed micropadaptivity-formalism was successfully tested in several empirical pilot-studies (Linek, Marte, & Albert, 2008).

The proposed ELEKTRA methodology can be suggested as a first framework for designing a broad spectrum of educational games. The framework is flexible and open for new technical developments and possibilities and bears the potential to integrate new scientific psycho-pedagogical concepts. Accordingly, the described methodology can be suggested as an open framework that can be adapted to the concrete needs and aims of game-designers, scientists and the target end users.

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