Enabling Individual Player Experience Through Adaptivity - Towards Building The Tracking Engine

Taha Dhiaeddine Amdouni, Damir Ismailović, Bernd Brügge
Institut für Informatik, Technische Universität München
Garching bei München, Germany
Email: {amdouni, damir.ismailovic, bruegge}@cs.tum.edu

***Abstract*—The future of serious games lies in the individualization of the gaming and learning experience and their adaptation to personal abilities and prerequisites, and this needs more Assessment in games.**

In this paper, we report about the process we adopted to design and evaluate a serious game on the iPad with mathematical teaching purpose for preschool children with a contribution to the Serious Games Community.

***Keywords*-Serious Games; Adaptivity; Evaluation;**

I. Introduction

Within, DANCE Research Group, at the Chair for Applied Software Engineering, under ward Prof. Ph.D. Bernd Brügge, we develop Adaptive Nonlinear Competing Digital Educational Games. These games were designed to reinforce academic standards for mathematics and target a variety of math skills following the Bavarian first grade curriculum (Staatsinstitut für Schulqualität und Bildungsforschung München, 2000).

Through the development process, we began with a non-adaptive game-prototype featuring a traditional, linear, level-based approach, that have acquired, step for step, more manipulable variables that could be fitted to the actual prowess and needs of the user playing with it.

Towards the adjustement of the adaptive behavior in the game, we employed a formative evaluation to investigate the relationship (dependencies and coherence) between adaptive variables and their impact on children motivation and their achievement.

II. Background

A. Game Engineering

Brügge et al. (2009) emphasizes – in his book "Object-Oriented Software Engineering - Conquering Complex and Changing Systems" – the two challenging factors along the development cycle of a software, namely, Complexity and change. These have been generally accepted to be the reasons why nowadays software engineers apply more agile development methodologies, to meet the demands and exceptions of today´s users. Furthermore specific users — preschool children aged 4 to 8 years old — need more focus, as well as their performance and the pedagogical value of the content delivered in the software

Therefore, assuring a built-in usability in a software, led us to integrating the evaluation process into the development cycle -> User-centered Design

B. Serious Games

1) Seriousness: Next to Fun, Motivation, Engagement, Brain Health and Play itself — Gameplay basics and rules — a serious game will not be considered as serious and will not fulfill an educational goal, if we would not pedagogically assign the learning content to the gaming experience and pragmatically seek the crucial balance between fun and education.

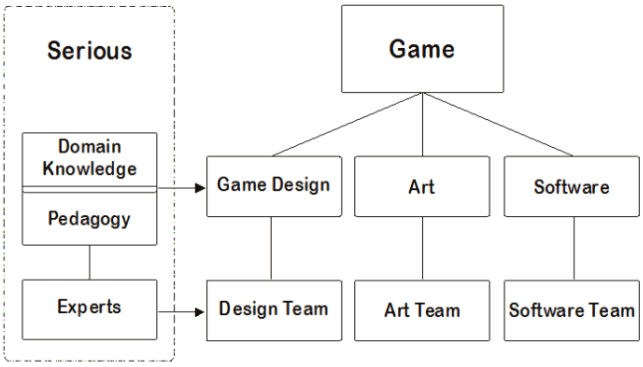
Although the definitions differ among researchers, if i would define Serious games, in the 21st Century, I would cite Clark Abt's definition from 1970.

Serious games are games that: "have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement. This does not mean that serious games are not, or should not be, entertaining." (Abt 1970)

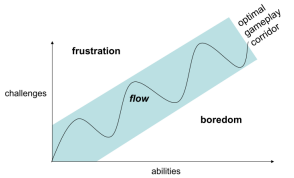
The seriousness in serious games, as we can see from Figure 1a on page 2, stems from the close collaboration and cooperation between game developers and experts to conceive games with well dosed learning content and responding to the psychological states of young children.

2) Immersion: Assuming that games, in general, wouldn´t be interesting for their players, if they don´t enjoy them. A serious game with a learning goal wouldn´t be benefit, if the player doesn´t plunge enough into the game and focus on the didactic goals of the game. Concentration and Motivation, the driving forces behind our actions, are seen as aspects that contribute to the player immersion upon an event or a task, what pushed the psychologist Mihály Csíkszentmihályi to outline his theory of Flow Figure 1b on page 2 as follow:

"People are most happy when they are in a state of flow— a state of concentration or complete absorption with the activity at hand and the situation. It is a state in which people are so involved in an activity that nothing else seems to matter." [2] Further he defines Flow as the ultimate state of immersion.



(a) Seriousness in Game-Based Learning - [1]



(b) Flow Theory - Mihály Csíkszentmihályi

(c) Zone of Proximal Development - Lev Vygotsky

Figure 1: Educational Research Theories applied on Serious Games

The ZPD approach introduced by Lev Vygotsky, a russian psychologist, presents an educational concept, that describes the notion of assisted performance.

Assisted performance defines what a learner can do with help, with the support of the environment, of others and of the self and simulates the notion of tutor in educational activities.

The contrast between assisted performance and unassisted performance identified the fundamental nexus of development and learning that Vygotsky describes as the zone of proximal development. [3]

The Scaffolding Theory, first introduced in the late 1950s by Jerome Bruner, a cognitive psychologist, relies on the provision of sufficient support to promote learning when concepts and skills are being first introduced to students. (Wikipedia)

Verenikina [4] presented an analysis of the metaphor of scaffolding in its connection to the Vygotskian concept of the zone of proximal development. These two metaphors closely resemble notionally. We can even admit, as shown Figure 1c on page 2, that the zone of proximal development defines the bounds where scaffolding is indeed needed.

Game designers refer to these prominent theories of Cognitive Development to develop serious games that stimulates the attention and actions of the players, in order to keep them focused and motivated at play and so to make the gaming experience playable and enjoyable. According to this theory a player will stay immersed in the Flow channel when he constantly experiences the right balance between the challenges of the game and his own skills.

C. Adaptivity

The gaming experience varies from player to another, from age to another, from gender to another, from a cultural background to another; and this, in fact, have led to the birth of the notion of adaptivity.

By adaptivity, i mean that the learning or/and gaming experience is adjusted, both in concept and form to the current needs and abilities, what we later call skills for the further of the thesis, of each pupil individually.

Later on, as the player evolues with the gaming experience and acquires more and more skills, the game engine creates adequate learning content and new game events, as it progresses; hereby adopt adaptivity the generative mode.

Thus we conclude that adaptivity stands for higher individuality.

I would redefine it at the end of this paper!

D. Evaluation Trends

- Serious Games Researchers recommend to adopt more the formative approach while evaluating digital educational games, since:
  1) Most earlier studies conducted in the filed of serious games have seeked to prove the effectiveness of these digital media in enhancing mathematical skills, in our case, but concluded that the effectiveness of serious games is still a mystery.
  2) Others have agreed that the issue of developing serious games is tricky enough, due to budgetary challenge (time consuming and costly nature of the developing process) and due to the challenge of ensuring a balance between learning and entertainment.

Over the last two decades, serious games researchers have published a wealth of articles suggesting ways that Games-Based Learning can be evaluated in terms of particular areas with particular measurements, experimental designs and analytical techniques. Through Serious games Research, researchers and developers attempt first to deliver clear theories about the effectiveness of DEGs and second to measure the educational attainment level. Several major reviews on educational games investigated to measure the effectiveness of games on their players but indicated no clear causal relationship between academic performance and the use of computer games. Moreover, researchers voiced misgivings towards this issue and contend that the effectiveness of computer games on learning is still a mystery. [5]

Others have seen the integration of external resources (learning media) with a game engine into a coherent and immersive game environment as difficult & The development of competitive DEGs is cost-intensive, and the markets are

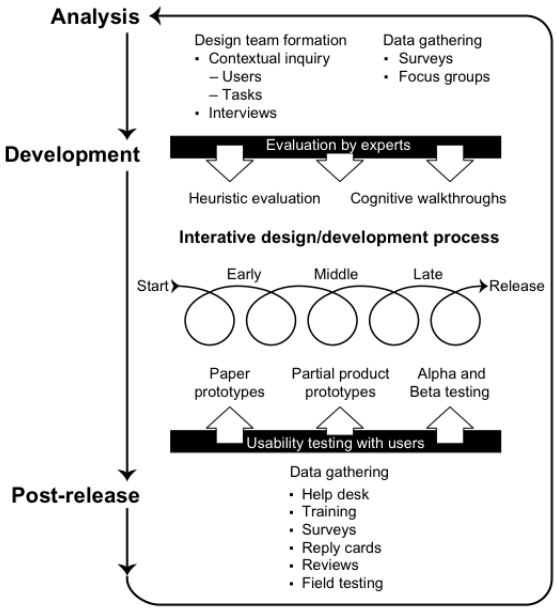


Figure 2: Spiral Reserach Model - [10]

narrow because DEGs may relate to limited age groups or specific curricula. [6]

On the other side, most researchers have agreed that, most gaming studies focused on learning conceptually, the nature of games promotes several vital skills such as metacognition, selective attention, problem solving, perspective taking, a chance to practice, thinking of alternative solutions, multiple modularities, multiprocessing, information literacy and are motivating (Blumberg & Ismailer, 2009; Charsky, 2010; Mason & Rennie, 2008; Davidson, 2008). [7]

Serious games researchers, having taken in consideration all the limitations and skepticism encountered in early studies evaluating the learning effectiveness of a game based laarning, take nowadays more care of achievement, motivation and fun factors in the gaming experience. Quinn [8] have concluded that we should: "focus more on making the interaction fun or useful—not on the learning aspects. In our community games, people are thinking, learning, experimenting, but we don't point to learning as an outcome at all. Learning takes place informally in all of the games."

Meyer [9] criticised contemporary educational researchers of being tagged as either positivist or interpretivist, two opposite epistemological paradigms in social studies, and proposed an alternative methodology which embraces pragmatism, called a Spiral Research Model as shown on Figure 2 on page 3. It incorporates a mixed-methods approach and multiple case studies in a practical way, in which the research question along with its changes over time, determines the choice of research methods.

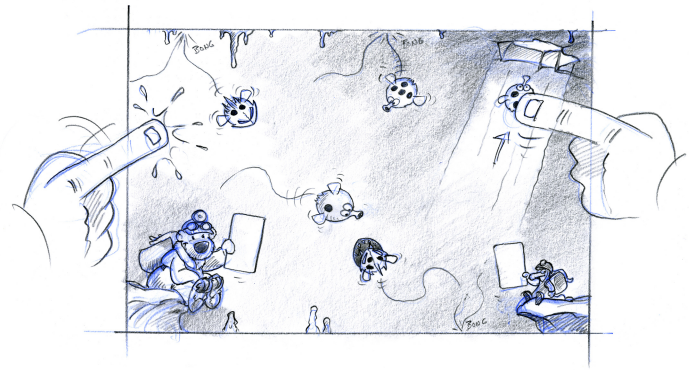


Figure 3: Children playing on the iPad - DRG-TUM

III. Case Study - Bug Game

A. Game Story

The Bug Game is a serious game used for learning. It should teach children counting numbers from 1 to 6. The game has two kinds of bugs, good and bad bugs. Each bug is carrying a number of dots on its back. The two actors, E&P should be holding one or two numbers which represent the number of dots carried by the good bugs. The main goal of the game is that the child has to recognize the numbers held by the actors and count the number of dots carried by each bug to know whether it is a good or a bad bug. When the child differentiates between good and bad bugs, he should be able to save as many good bugs as he can by sending them through an exit cave before being eaten by the bad bugs. The child wins the game if he succeeds to save more than half of the good bugs.

The setting is a cave. Bugs enter the cave through a hole in one corner. Each bug has a certain number (between one and six) of glowing- dots on its back. In the other corner is an exit. At the bottom left and right corner the two main characters, E&P, are positioned each holding up a sign showing a different digit between 1 and 6. Only bugs which have the same number of dots on their back as the numbers held by E&P are allowed to leave the cave. The child's task is to help the good bugs to leave the cave by throw- ing them towards the exit and prevent the bad bugs from leaving by squishing them. If bad bugs hit good bugs they eat them; if they hit each other they multiply. Bugs that hit the border of the screen bounce off. The flying speed of the individual bug depends on the number on its back – bugs with a higher number are faster. If a bad bug manages to leave the cave, the game ends. A score about the number of good flies that left the cave is kept. Good bugs that leave the cave by chance are counted as well. Thirty good bugs enter the cave and when they all have left the cave or been eaten the game ends.

The game structure offers the option to include adaptivity on different levels. This hides the linear structure of the

game and gives the player the feeling that his/her actions have an impact on the game world. It creates the feeling of playing the game the way he/she wants, with a sense of agency and control. This increases the flow experience (Sweetser & Wyeth, 2005).

B. Evaluation Process

(POI: Prototype, Observe & Interview)

The rigor of the study is important in order to generate credible and trustworthy theories and results.

The typical evaluations encountered in my literature review have adopted the principle of proofing the positive effects of serious gaming on the learning experience and neglected the fact that the integration of learning content within games need to be well analyzed from the pedagogical, psychological and pragmatical point of vue.

The functional requirements are the business functions that the system is to perform.

The requirements in our game should also be met after enabling the adaptive mode, what led us conduct such a process evaluation.

Backwards adjustement of the adaptive mode.

The iterative process shows testing throughout development

Admitting that a process evaluation needs to be considered right at the start, and built into a project's logic model to attain Specific, Measurable, Achievable, Realistic and Time-bound objectives. We adopted this principle and integrated our evaluation into the implementation process of the game.

We applied qualitative research methods by interviewing experts and by observing children while playing. We iteratively developed a serious game with experts (pedagogics, psychologists, professional game-developers, serious game researchers, students and players).

During the development process we carried out informal, conversational interviews with all participants in every iteration. The constructed game helped us to to provide examples to the given questions, and helped the experts to reflect about given answers.

Additionally we used this serious game to observe children while playing, for being able to provide more data for the experts.

Finally we executed retrospective interviews with experts based on the given work with them.

The process can be repeated for the other mini-games. An overview of the steps of the study is given on Figure 4 on page 4.

The evaluation process have been conducted since the prototype phase.

Important Factors in Game Evaluation:

- Typical usability outcomes: Task Time & Errors (Game Aspects)
- Users´ subjective experiences and attitudes towards the game. (Users Aspects)

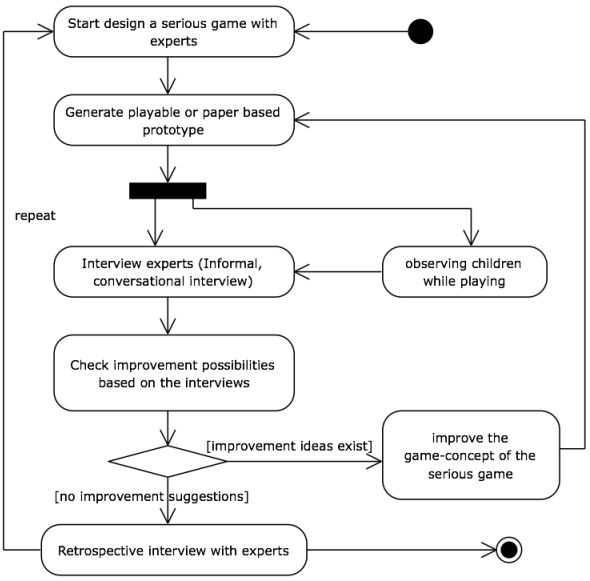


Figure 4: Logic Model - [11]

It's like having someone look over your shoulder during the development phase to help you catch things that you miss.

1) Play-based Observation: Nielsen ...

Gone from the emotions of the child, which are observed (effect), we search for the reason/trunk (cause) of success and/or failure. The cause can be part either of the GameAspect, or of the LearningContentAspect; which should be adapted accordingly to player needs.

We observed a small sample of children, with the intention to reduce all possible intervening variables I have chosen to conduct a test on each child (Case Study of 5 children) showing an increase in mastering both of recognition and addition & an increase in hand having the iPad as a learning instrument.

We have contacted psychologists to assist us on the evaluation days in understanding children's emotions.

A group of helpers were mobilised to measure the impact of each variable on a group of children, another one to evaluate the emotions, a third one to measure the time taken for each level or until the first right answer or until the first disenjoyment/angryness per child.

C. Experts´ Interviews

First RQs!

The Comments and interpretation of experts acted as a validating factor to the Usability and playability of our game.

The iterative usability testings, since throughout them, many Usability Testing issues were identified and remedied, ...

1) Feedback: The idea of adaptivity through Aptitude-Treatment interaction approach by dynamically generating

Figure 5: Remote Tool for Experts´ Interaction - Taha

the feedback given by the main characters in the game (E&P) would be a fairly time- and cost-intensive process.

The necessity of a **complex feedback** depends strongly on the task. Tasks which require a complex knowledge and understanding of the subject require detailed feedback while tasks which primarily serve for repetitive training — when failure happens mostly due to a lack of practice — do not require such detailed feedback.

2) Assessment of data for user interpretation: Underwood Project - Leading Server-based Solution from USA

Identifying the Right Kind of Challenges
Addressing Different Skill Levels
Players Must Be Rewarded
Appropriately Collecting and Completing
Perceptual-Motor Skill Requirements
Change over Time
Overall Quality (Also Known As "Fun")
Ease of Use
Challenge & Pace

3) How would we track the learner?: Monitoring Model - Damir - User Model (Skills + State + Problems/Limitations)

4) Which in-Game Data Should be taken in consideration?: Enough in-game data for system self-evaluation.

D. Remote Experts´ Interaction

Remote Tool Concept

Aim to define the expert player/learner model (Mittelwert der Messungen)

E. Results

Adaptive variables related to Game Elements or Learning Activities

Adaptive variables linked to each other

make meaningful connections between what we observed and what we discussed with Experts earlier!!! We clearly linked the observed playing-learning process to concepts, principles, and theories, evoked by Serious Games Researchers.

- Develop a game story, that would simulate the real-life use of the learning goals intended. (Real-World-Simulation of Mathematical Issues)
- Software made on intuitive-operated touch-devices may even need tutorials to guide first-time users through the gaming environment. (...)
- Ensure logical coherence and connections between adaptive variables
  - Navigation between mini-games (Skills required to pass to another mini-game {Minimal Requirements})
  - Build a logical Skills-Acquisition-Model for the mini-games (Recognize; Draw; Count; Geometry; ...)
  - Tasks, events and Skills should be connected (...)
- Recalculate Scores (Scores are motivational); If leaderboards won´t exist, there wouldn´t be neither Game Center (App Store) nor Opeinfeint.
- Link adaptive variables to Game & Learning Elements
- Study Adaptable Variables coherencies and dependencies and build these in the expert learner model.
- Bound Adaptable Variables applying the flow theory
- Bound Variables due to the Device used (Device Screen) {Total number of Bugs; Duplication; Entering Rate (Until no bugs on scrren -> Once double entering rate)}
- Integrate more variables to better track the player through the gaming story.
- TUTOR (Comparaison with the Expert-Learner-Model integrated in the Game) (Capability vs. Instructional Content -> intended learning goals/outcomes)
  - Easy the Task/event; when needed
  - Scaffold the task/event; when needed
  - during instruction, the expert should be able to define the limits of understanding of the Learner, they must successfully pass on knowledge and they must be able to competently assess that the Learner has understood.

F. Integration of Results (Reuse)

Re-description of the conceptual framework for Adaptivity

The Game Engine provides the Tracking Engine with an information protocol about the actual user state through observational variables and already acquired skills. The Tracking Engine compares the resulting information with the Expert User Data, to acquire an actual image of user experience. The Reasoner Engine, based on pedagogical, psychological and gaming rules analyzes the resulting monitoring information and on the basis of System Evidence and/or System Limitations, recommends the next best adap-

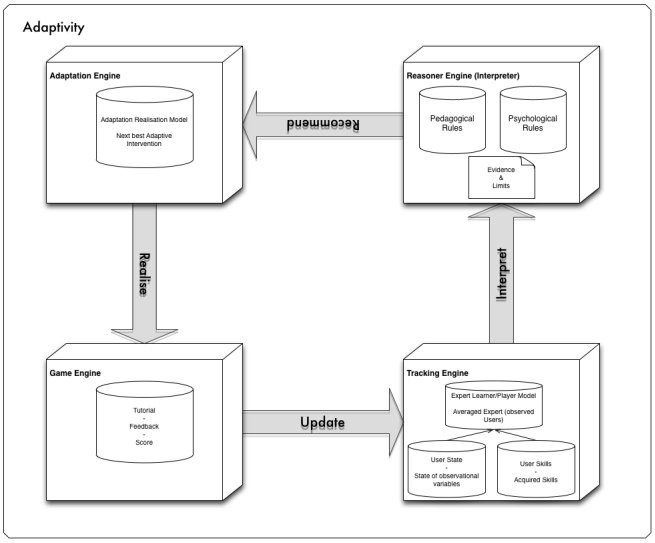


Figure 6: Conceptual Framework of Adaptivity in Serious Games - Taha

tive intervention, that would ensure either a help-giving service or a scaffolding effort.

IV. Conclusion

Even though the encountered limitations conducting observational studies on preschool children, we benefited a lot from the emotions to identify problems. The interpretation of the emotions through Experts acted as a validating factor for our Analysis of the observational data.

Redefine the conceptual framework of Adaptivity with (Betonung) the notion of Tracking, Monitoring, ...

Acknowledgment

The authors would like to thank... more thanks here

References

[1] M. Masuch, "Digitale Lernspiele," *Fachhochschule Trier*.

[2] M. Csikszentmihalyi, *Flow: The Psychology of Optimal Experience*. Harper Perennial, 1990, vol. 8, no. 1. [Online]. Available: http://www.jstor.org/stable/1511458?origin=crossref

[3] L. S. Vygotsky, *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press., 1978. [Online]. Available: http://books.google.com/books?id=RxjjUefze_oC\&printsec=frontcover\&dq=Minds+in+society:+the+development+of+higher+psychological+processes\&source=bl\&ots=ofCYY2u_au\&sig=acXi4EvogScDL95OKgNQWl7Kxvg\&hl=en\&ei=Onz-S8-PLIOT4gbqseGFDg\&sa=X\&oi=book_result\&ct=result\&resnum=4\&ved=0CDAQ6AEwAw\#v=onepage\&q\&f=false

[4] I. Verenikina, "Understanding Scaffolding and the ZPD in Educational Research," *Faculty of Education, University of Wollongong, NSW, Australia*, 2004.

[5] F. Ke, "A case study of computer gaming for math: Engaged learning from gameplay?" *Computers & Education 51 2008 Elsevier Ltd*, vol. 51, no. 4, pp. 1609–1620, Dec. 2008. [Online]. Available: http://linkinghub.elsevier.com/retrieve/pii/S0360131508000523

[6] E. L.-c. Law and M. Rust-kickmeier, "80Days: Immersive Digital Educational Games with Adaptive Storytelling."

[7] C. T. Panagiotakopoulos, "Applying a Conceptual Mini Game for Supporting Simple Mathematical Calculation Skills: Students Perceptions and Considerations," *World Journal of Education*, vol. 1, no. 1, pp. 3–14, Apr. 2011. [Online]. Available: http://www.sciedu.ca/journal/index.php/wje/article/view/150www.sciedu.ca/wje

[8] C. N. Quinn, *Designing MLearning: Tapping Into the Mobile Revolution for Organizational Performance*. Pfeiffer, An Imprint of Wiley, 2011. [Online]. Available: www.pfeiffer.comwww.designingmlearning.com.

[9] B. Meyer, "Proceedings of the 4th European Conference on Games Based Learning," no. October, 2010.

[10] C. M. Barnum, *Praise for Usability Testing Essentials*, 2011.

[11] D. Ismailović, "Individual Learning Experience with Adaptive Serious Game," Doctor, Technische Universität München, 2012.