

# Pragmatism Within Adaptivity — 21st Century Technological-Innovation-Driven Evaluation Framework

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Figure 1. Children playing on the iPad - DRG-TUM

**Abstract**—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.

As the digital world evolves and games-based learning flood the market, play was replaced by computer games, ranging from play consoles to educational software on mobile devices such as smartphones and tablets.

In this scope, researchers have struggled to present comprehensive and appropriate guidelines and grounded theories to designing and evaluating serious 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.

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

## I. INTRODUCTION

A new milestone in the technology evolution have been finalized. Nowadays technology provide us with environments that can be adapted to the individual player/learner, what makes the experience personal, unique and contextualized. This encouraged the game developers to develop digital educational games that support a personalized learning ex-

perience by adapting the game's story to individual preferences, by providing the possibility of explorative learning processes, by enabling the realization of different stories and entirely different game situations, also for a variety of different learning domains based on more or less the same pool of story units, patterns and structures as well as learning and gaming concepts and elements/objects.

...

It's time for kids to crunch numbers in a fun way! While math can be an intimidating subject for some kids, there are plenty of games for kids to enjoy their learning experiences. The best part is that kids won't know they are learning because they'll be having so much fun playing math games. These elementary school level math games are a win-win for teachers and parents who want to motivate their kids to sharpen their math skills!

...

In DANCE Research Group - Chair for Applied Software Engineering - Technische Universität München - we're responsible for designing serious educational iPad games for preschool children. 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).

An important feature of the game is its adaptive behavior which adapts the gaming environment and the learning content to the child's individual skill level. [1]

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.

— Diagramm (Design Process - Non-Adaptive TO Adaptive)

Therefore the notion of user-centered design arises ... (definition needed)

## II. BACKGROUND

### A. Serious Games

Although the definitions differ among researchers, if I would define Serious games, in the 21st Century, I would

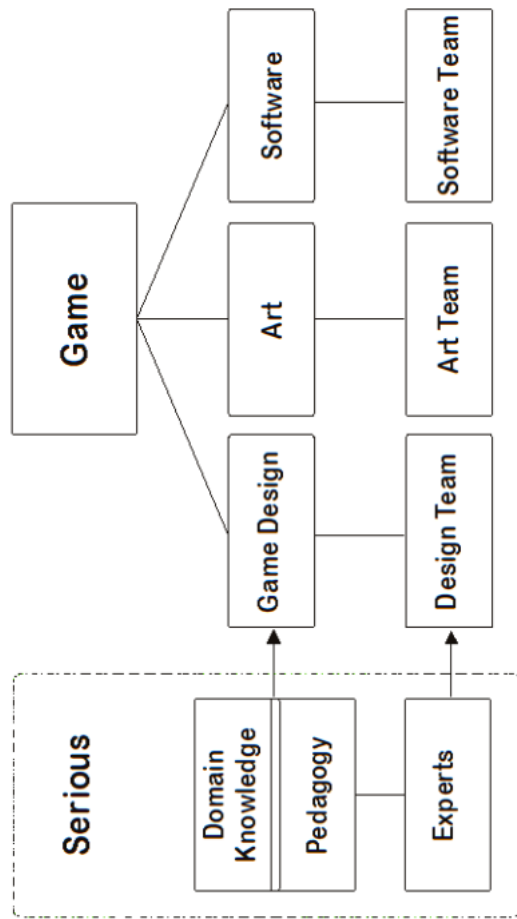


Figure 2. Seriousness in Game-Based Learning - [2]

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 2 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.

### B. Pedagogical & Psychological Patterns

To Brain Health, as a pattern;  
To Play, as a powerful mediator for learning;  
Play & Learning: Vital connection

Leo Buscaglia have seen it paradoxical, that many educators and parents still differentiate between a time for learning

and a time for play. Without seeing the vital connection between them.

- 1) *Game-Flow*:
- 2) *Zone of Proximal Development*:
- 3) *Scaffolding*:

### C. Adaptivity

Adaptive vs. Generative;

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 evolves 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.

(Shute and Zapata-Rivera, 2008) define adaptivity as: "The capability exhibited by an organic or an artificial organism to alter its behavior according to the environment."

A more scientific definition that clarifies this approach would be: "a non-invasive approach that enables a serious game to learn from learner's behavior by intelligently monitoring and interpreting learner's actions in the game's environment and adjusts automatically learning and game elements according to the student's individual ZPD as necessary."

Where we note, that Adaptivity describes in this definition the following factors:

- non-invasiveness: Does not disrupt the gaming experience.
- intelligent monitoring Behavior (in form of Action) is observed while playing in a non-invasive manner.
- interpreting learner's actions: We can interpret this in the following way: The system can recognize the learner's skills based on the Knowledge Space Theory.
- ability to learn from experience: Learning from behavior.
- adaptive intervention: Adjusts automatically learning and game elements.

So stands adaptivity for higher individuality.

Typically the learner's needs are represented within a user model, with the system being able to adapt certain system variables using this model. [3]

### D. Model

The Game System consists of four modules or engines.

The game engine (GE) provides the non-adaptive parts of the game, is the user interface to the system and provides information on the learner's action in the game to the skill assessment engine (SAE). The SAE updates the

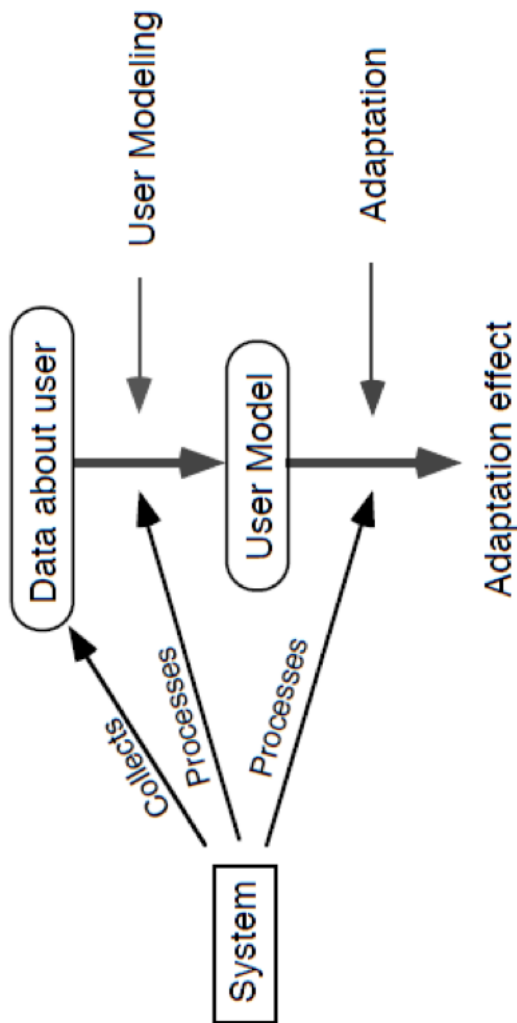


Figure 3. Classic loop "user modeling - adaptation" in adaptive systems – [3]

learner model (i.e. the skill state likelihoods). The resulting information about the learner's skill state and its changes are then forwarded to the Educational Reasoner (ER), the pedagogical part of microadaptivity.

Based on pedagogical rules and learning objectives, the ER gives recommendations on adaptive interventions to the adaptation realization (AR) module which maps the abstractly formulated educational recommendations onto more concrete game recommendations.

In this mapping process, data on game elements and information on previously given recommendations are considered.

The game recommendations are then forwarded to the GE which realises them as concrete adaptive interventions in the

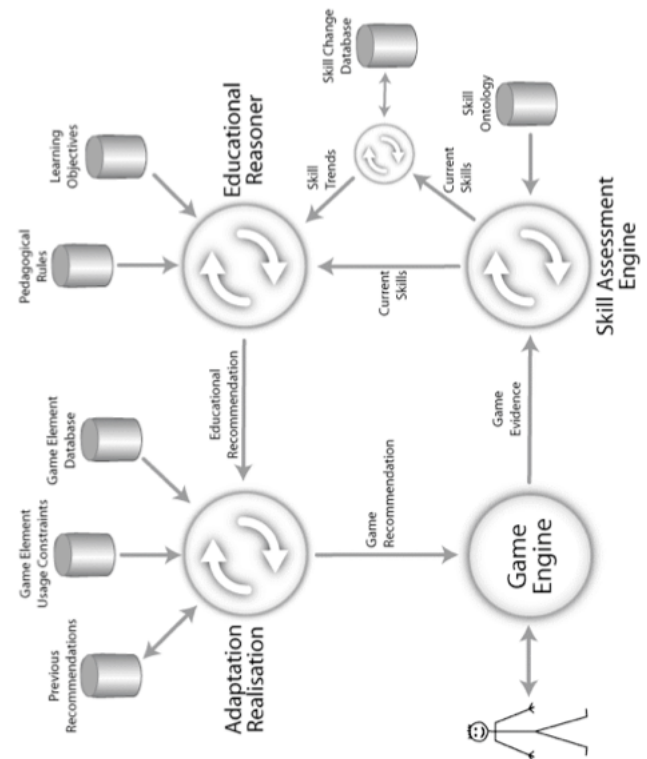


Figure 4. Game Architecture - [4]

game.

In the forward of the thesis, i would focus on the Educational Reasoner, which i would redefine, in our final Model as Pedagogical Reasoner, since it would handle both aspects of our game, gaming and learning elements.

Here arises the need of such a pilot evaluation; to define general rules to the whole game process, pedagogical rules to the learning content and even psychological rules to keep the gaming experience in the optimal gameplay corridor as mentioned on Figure 5 on page 21. The Game Framework consists of four Modules — which will be in Damir Ismailovic' Ph.D. Thesis:

- Learner Module (User Authentication & Update Module)
- The Evaluator Module (Performance Assessment Module) [Skill Assessment: skills acquired, skills required for the next level]
- Pedagogical Reasoner (Reuse of Experts interviews Results)
- Game State Module (actual state, next preferably adaptive intervention)

### E. Research Trends

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. [2] 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 narrow because DEGs may relate to limited age groups or specific curricula. [3] 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 & Ismail, 2009; Charsky, 2010; Mason & Rennie, 2008; Davidson, 2008). [4]

Serious games researchers, having taken in consideration all the limitations and skepticism encountered in early studies evaluating the learning effectiveness of a game based learning, take nowadays more care of achievement, motivation and fun factors in the gaming experience. Quinn [6] 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.” So, from developers’ sight, we should provide a balance between teacher-assigned and student-selected tasks in the learning content to assure a funny, motivational and playable game.

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### III. EVALUATION DESIGN - USER-CENTERED DESIGN

Meyer [7] 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. 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.

Preschool children? Age?

Therefore we adopted this principle, since we would over and over adjust the game to his players, leading to a user-centered design.

#### A. Methodology - Spiral Research Model

The iterative process shows testing throughout development

#### B. Logic Model - SMART objectives

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 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

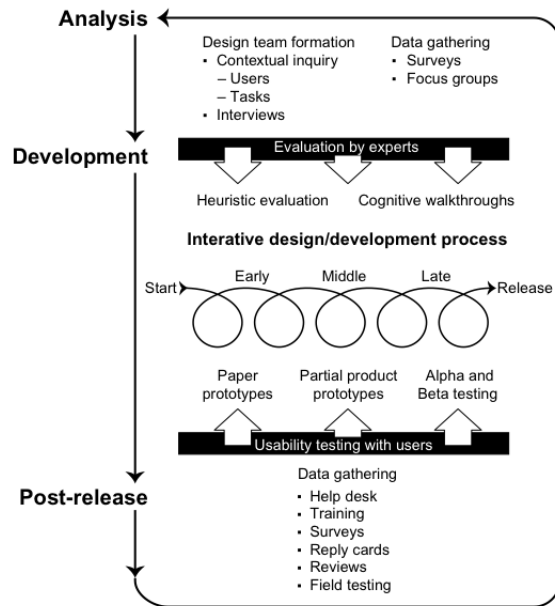


Figure 5. Spiral Research Model - [5]

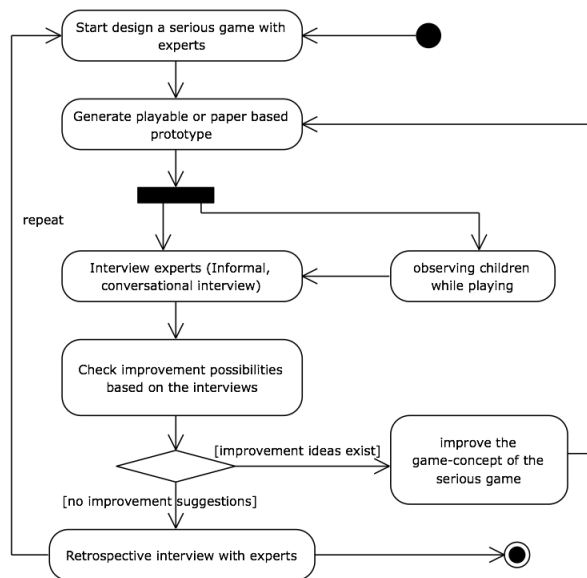


Figure 6. Logic Model - [1]

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 10 on page 55 and Figure 11 on page 56.

### C. 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

### D. How would we track the learner?

Monitoring Model - Damir - User Model (Skills + State + Problems/Limitations)

### E. Which in-Game Data Should be taken in consideration?

### F. How would we interpret the in-Game data?

Experts' interpretation?

## IV. EVALUATION PROCESS

The evaluation process have been conducted since the prototype phase.

### A. Rigor - "Backwards Adjustment of Micro-Adaptivity"

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

Projects need clear objectives that describe what they aim to do and how they will do it. In general, the clearer the objectives, the easier they will be to measure. If it is not clear what the project is trying to achieve, it will not be possible to measure whether or not it has been successful.

The typical evaluations encountered in my literature review have adopted the principle of proving 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.

### B. Methods

Formative (TAHA) vs. Summative (CHRISTINA) Evaluation

Formative Evaluation is a bit more complex than summative evaluation. It is done with a small sample of users to "test run" various aspects of instructional materials. It's like having someone look over your shoulder during the development phase to help you catch things that you miss.

Formative evaluations strengthen or improve the object being evaluated - they help form it by examining the delivery of the program or technology, the quality of its implementation, and the assessment of the organizational context, personnel, procedures, inputs, and so on.

Summative evaluation provides information on the product's efficacy (its ability to do what it was designed to do), is

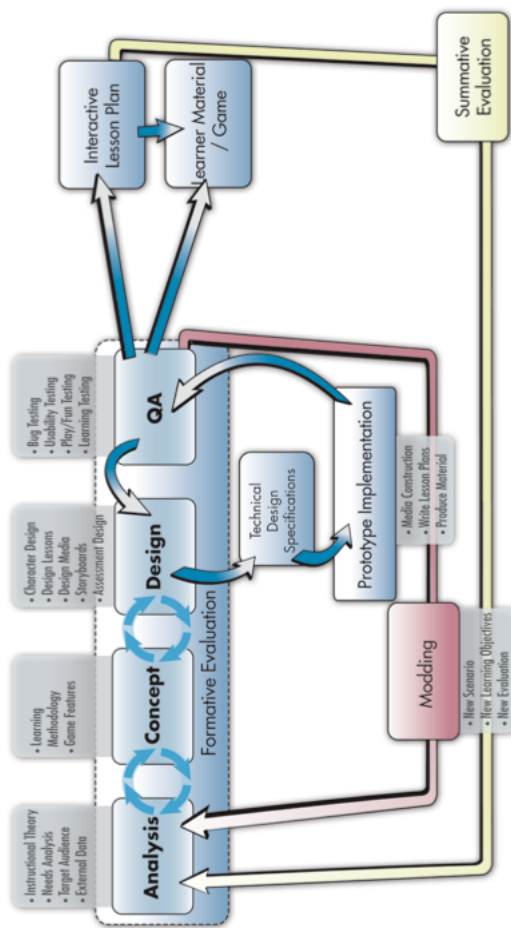


Figure 7. Game Engineering Design Model - [6]

typically quantitative, using numeric scores or letter grades to assess learner achievement.

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.

### C. Results

- Serious Games Researchers recommend to adopt more the formative approach while evaluating digital educational games, since:
  - 1) Most earlier studies conducted in the field of serious games have sought to prove the effectiveness of these digital media in enhancing
- Pedagogical Reasoner

- variables zusammenhänge und Abhängigkeiten
- Variables (Adaptable & Non-Adaptable) limitations/Bounds

### D. Validity

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 schönheitsfehler sowie major usability problems were identified and remedied, ...

## V. CONCLUSION

### ACKNOWLEDGMENT

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

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