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 is 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 experience 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 (Gaming vs. Learning)

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

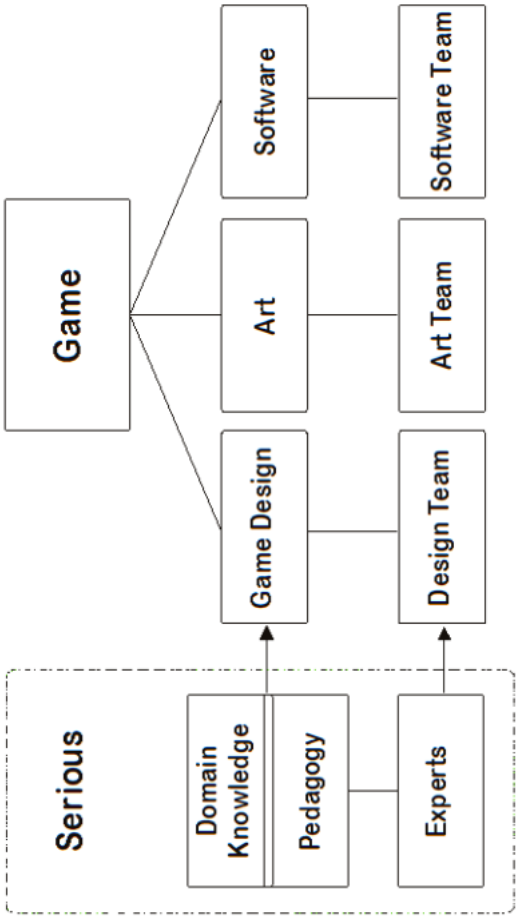

Figure 2. Seriousness in Game-Based Learning - [2]

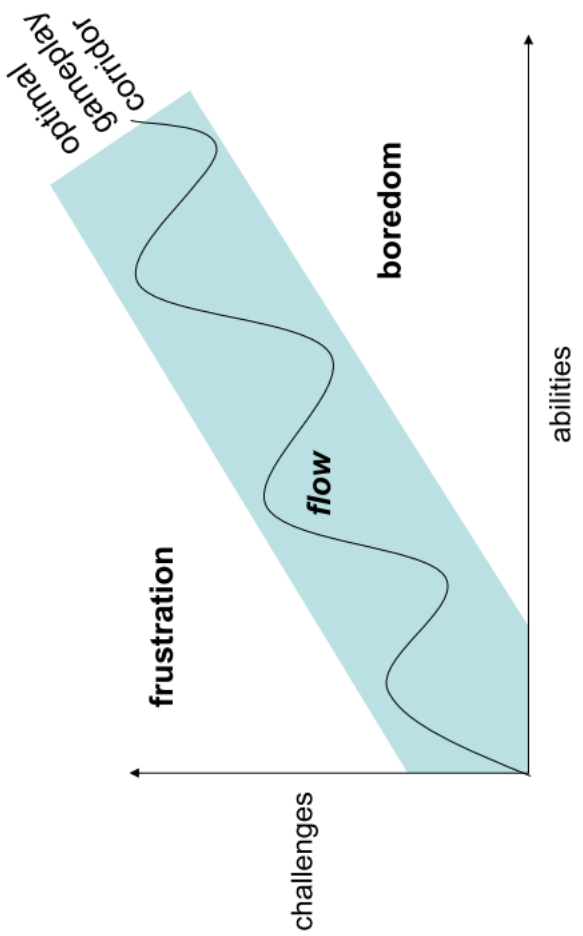

Figure 3. Game Flow

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;
- To FUN;
- Play & Learning: Vital connection
- Learning theories (211211-1408.pdf) {Conceptually; Try&Error Principle; ...}
  - Active, critical learning principle
  - Psychological moratorium principle
  - Committed learning principle (Nachhilfe App)
  - Identity principle
  - Self-knowledge principle
  - The probing principle
- "A recent review of game-based learning research indicated that most gaming studies focus on learning conceptually — concepts like general reasoning, creativity, system understanding and decision making, which does not demand special knowledge of subject areas (Bateson, 1972)." [3]
- 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.
- Immersion -> Effective Learning

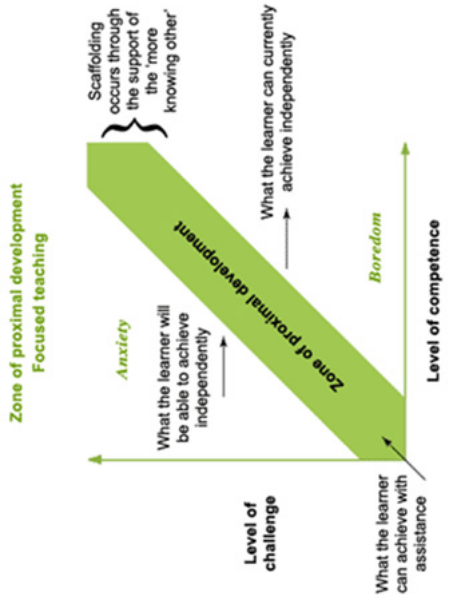

Figure 4. ZPD & Scaffolding

1) Game-Flow: Games wouldn´t be interesting for their players, if they don´t enjoy them.

Furthermore 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 3 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." [4]

Further he defines Flow as the ultimate state of immersion.

Game designers refer to the Flow Theory, 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.

2) Zone of Proximal Development: In Vygotsky's words, "what the child is able to do in collaboration today he will be able to do independently tomorrow" (Vygotsky, 1987, p. 211).

3) Scaffolding: 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 [5] 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 4 on page 3, that the zone of proximal development defines the bounds where scaffolding is indeed needed.

C. Adaptivity

Adaptive vs. Generative;

The gaming experience varies from player to another, from age to an- other, 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.

(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 fol- lowing 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. [6]

D. Model

The Game System consists of four modules or engines.

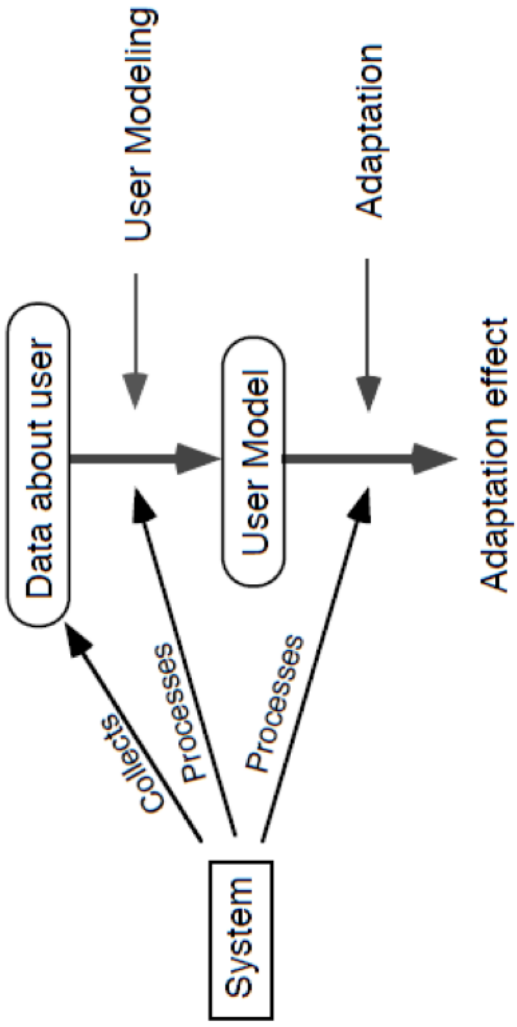

Figure 5. Classic loop "user modeling - adaptation" in adaptive systems – [6]

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 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 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 mentionned on Figure 5 on page 21. The Game Framework consists of four Modules — which will be in Damir Ismailovic Ph.D. Thesis: [1]

- 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

- Analysis of the literature review

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. [3]

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. [8]

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

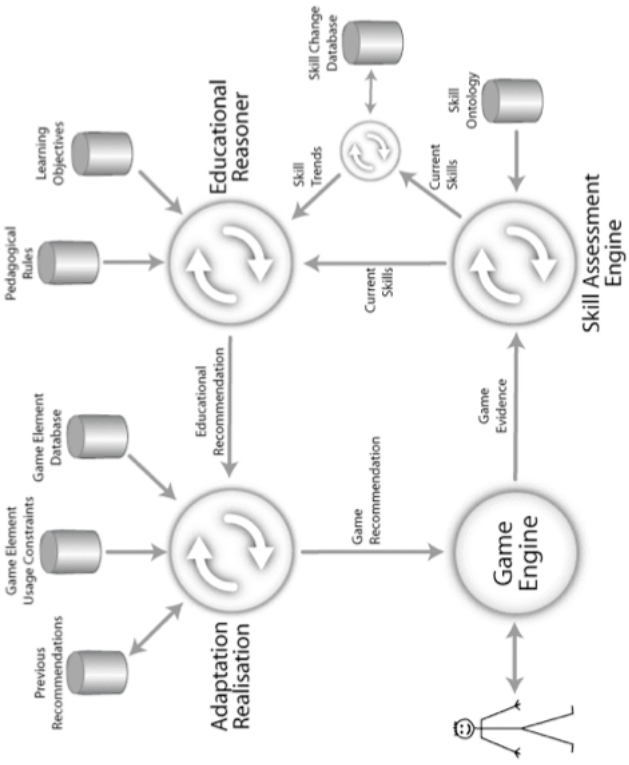

Figure 6. Game Architecture - [7]

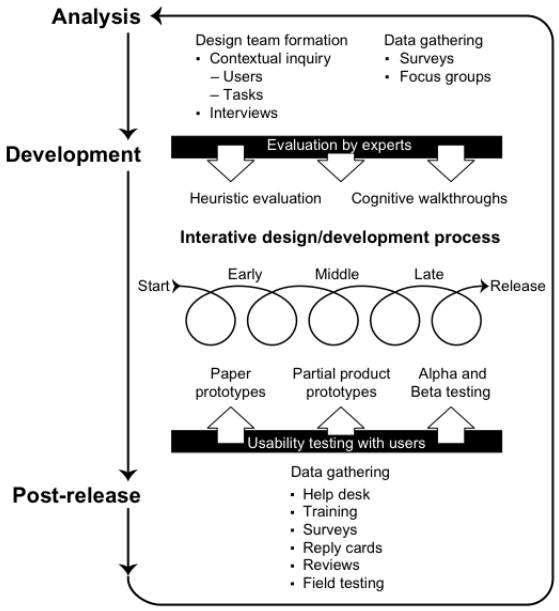

Figure 7. Spiral Reserach Model - [12]

modularities, multiprocessing, information literacy and are motivating (Blumberg & Ismailer, 2009; Charsky, 2010; Mason & Rennie, 2008; Davidson, 2008). [9]

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 [10] 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.

III. Evaluation Design - User-Centered Design

Meyer [11] 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 7 on page 5. 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.

This emergent design gains more and more acceptance among researchers and involves different user-centered techniques, that could and should be combined such as structured usability tests, rapid iteartive testing and evaluation or open-ended usability tasks, paper prototypes, and empirical guideline document.

Since

- Development (From Game Engineers´ Sight)
  - mini-games treating one subject (math), trivial, intuitive and co-op program with schools
  - We began with prototypes -> Interviews with Experts -> Observation -> Analysis (with Experts) -> Re-Design -> Re-Test -> ... -> Final Product. (POI: Prototype, Observe & Interview)

A. Methodology - Spiral Research Model / Mixed Methods (Formative&Summative) / User-Centered Design

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,

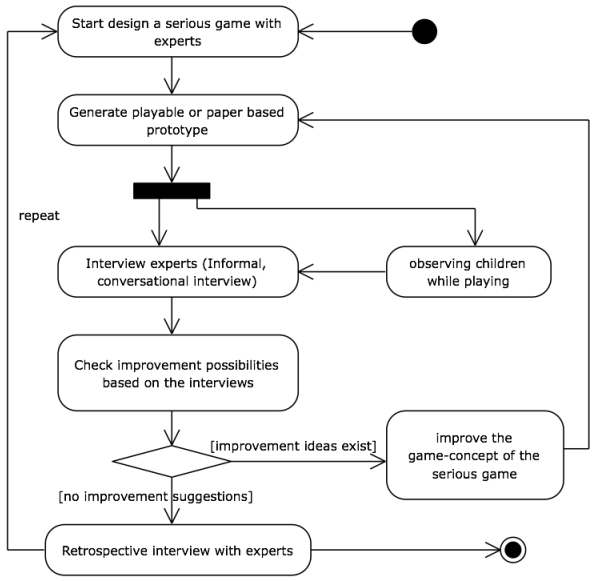

Figure 8. Logic Model - [1]

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 10 on page 55 and Figure 11 on page 56.

B. 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

C. How would we track the learner?

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

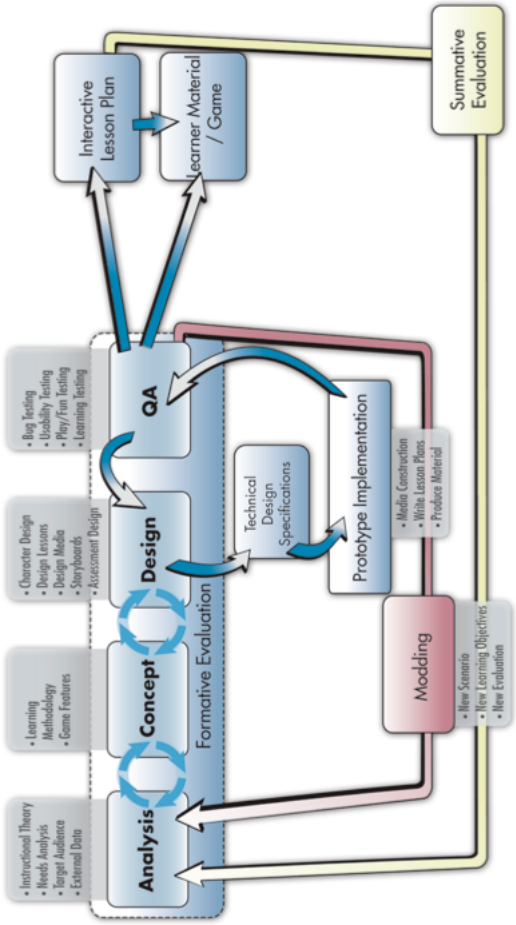

Figure 9. Game Engineering Design Model - [13]

D. Which in-Game Data Should be taken in consideration?

Enough in-game data for system self-evaluation.

E. How would we interpret the in-Game data?

Experts´ interpretation?

IV. Evaluation Process

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)

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 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 LearningCon- tentAspect; which should be adapted accordingly to player needs.

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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 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.

B. Play-based Observation

"no one knows how best to make an interface than someone who uses it day after day after day. We play our games a lot, but we can never play them as much as our fans do." - Soren Johnson.

We observed a small sample of children, with the intention to reduce al intervening variables I have chosen to conduct a test on each child (Case Study of 5 to 10 members) showing an increase in mastering both of recognition and addition & an increase in hand having the iPad as a learning instrument better than play consoles. Because of the fact that giving a child the possibility to try on early age to interact with new technologies such as tablets and smartphones enriches their Way and let them be interactive, play and enjoy the innovative gameplay & learn automatically.

C. Results

Contribution to the Serious Games World, overthere;

- 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.
- Develop a game story, that would simulate the real-life use of the learning goals intended.
- Software made on intuitive-operated touch-devices may even need tutorials to guide first-time users through the gaming environment. (...)
- Concentrate on the Pedagogical Reasoner in the Game Engine.
- Ensure logical coherence and connections between mini-games responding to the grounds of the Knowledge Space Theory.
  - 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 (...)
- Use Audio for Feedback or Rewards.
- Recalculate Scores (Scores are motivational); If leaderboards won´t exist, there wouldn´t be neither Game Center (App Store) nor Opeinfeint.
- Study Adaptable Variables coherencies and dependencies and build these in the expert learner model.
- Bound Adaptable Variables
- 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.

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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Studies on	dealing with	Number
Development of serious games	fun, motivation, age	enough
Guidelines to Development	Psychology & Pedagogy	120 & 62
Mobile Learning	Touch Devices & new Learning goals	NEW
Game Flow	Mihaly Csikszentmihalyi´s Theory (Psychology) DOB 1990	99
Zone of Proximal Development	Lev Vygotsky´s Theory (Psychology) DOB 1934 Rebirth 1978	53
Scaffolding	Jerome Bruner´s Theory (Pedagogy) DOB 1950	51
Adaptivity (Elektra)	Tutor-Adaptivity with new trends	10 & more
Adaptivity (others)	Conflict Resolution & Adaptation Realisation	14
Evaluation of Usability Systems	Usability Testing & Program Evaluation Guidelines for Software Engineers (general)	10
Evaluation	Aim, Logic Model, Evaluability Assessment - Comparaison Criteria (Motivation, Challenge, Success in Tasks, ...) - Use Emotions to identify Problems -	165
Serious Games for Math	Real-World-Simulation of Mathematical Issues	4
Assessment in Games	User Modeling - User Tracking - Pedagogical Reasoner in Game Engine - ... - (Underwood with a server based product USA)	10
		Total: 200 Papers

Table I