EVALUATION OF THE IMPACT OF MICRO ADAPTIVITY IN SERIOUS GAMES.

EVALUIERUNG DER AUSWIRKUNG VON MIKRO-ADAPTIVITÄT IN LERNSPIELEN.

BY

TAHA DHIAEDDINE AMDOUNI

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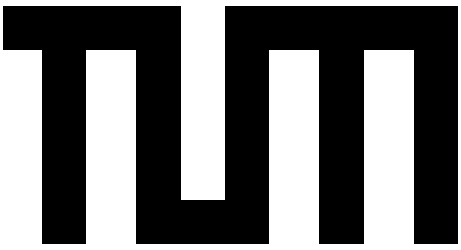

Chair for Applied Software Engineering
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Technische Universität München
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I dedicate this work

First to my parents who gave me the chance to study in Europe.

Second to the members of the Dance Research Group, colleagues and academic advisors from the Chair of Applied Software Engineering.

Third to the young generation gamers for whom the game was designed.

2011-2012

ABSTRACT

As more and more computing becomes about ubiquitous personal mobile platforms like iPhone, iPad, Nintendo DS, Android, and many flavors of mobile phones & tablets, the opportunities to create unique serious games is more possible then ever before.

Imagine if your child learns maths with assistance through playing, so you can lean back and spare you a Lerner and forward effort.

Imagine if we could combine the gameplay with all the enjoyment & motivation in it and the learning with all the difficulties that children could encounter in their first steps; bringing out a serious game on the iPad.

With assistance we, "Dance Research Group", mean that: based on the theory of the zone of Proximal Development [Vygotsky´s Psychological and Pedagogical patterns], learns your child more with a little help when needed, what we call further "dynamic adaptivity"; this approach let the game adapt himself to the abilities of your child giving him the favor to enjoy the game and learn implicit and effectively.

PUBLICATIONS OF THE D.R.G.

D.R.G. stands for **DANCE** Reserch Group — **D**eveloping **A**daptive **N**onlinear **C**ompelling **E**dutainment-Games.

- 2008 - Barwin on the Beagle - Towards A Framework for Behavior Aware Intelligent Learning Systems — Ismailović and Pagano [80]
- 2009 - On the Application of different Research Methods in Software Engineering — Ismailović et al. [82]
- 2011 - WeMakeWords – an Adaptive and Collaborative Serious Game for Literacy Acquisition — Ismailović et al. [83]
- 2011 - Drehbuch Emil & Pauline in der Höhle — Bartl [7]
- 2011 - Master Thesis - Evaluation of a serious game — Kolb [101]
- 2011 - Bachelor Thesis - An Adaptive Serious Game for Preschool Mathematics on Mobile End Devices — Simeonova [166]
- 2011 - Bachelor Thesis - A framework for modul based adaptive Serious Games — Waldmann [200]
- 2011 - Master Thesis - A Quick Prototyping Tool for Serious Games with Real Time Physics — Haladjian [68]
- 2011 - Conference Paper - A Quick Prototyping Framework for Adaptive Serious Games with 2D Physics on Mobile Touch Devices — Haladjian et al. [69]
- 2011 - Bachelor Thesis -Bug Game: Learning Math in a Serious Game for iPad — Farah George [45]
- 2011 - Master Thesis - Domain-independent Framework for story driven game-based learning — Barbara [5]
- 2012 - Diploma Thesis - Evaluation of the Impact of Micro-Adaptivity in Serious Games — Amdouni [4]
- 2012 - Ph. D. Thesis - Adaptivity in Serious Games —Ismailović [79, 78]

"Watch a man
at play for an hour
and you can learn
more about him
than in talking to him
for a year."
(Plato, 427-348 v.Chr.)

— Bopp [12]

ACKNOWLEDGMENTS

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I am also indebted to the stakeholders, children, kindergarten that participated in the evaluation and the experts and teachers who contributed to a better and easier analysis of the data gathered.

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Part I

INTRODUCTION

1 INTRODUCTION

1.1 PHILOSOPHY

The purpose of this work is to evaluate the impact of adaptivity which we would integrate in a serious game designed on the iPad for preschool children aged from 4 to 8.

Evaluation relies on objectivity, otherwise the outcomes wouldn´t be neither valid nor reliable.

1.2 OVERVIEW OF THE SCIENTIFIC RESEARCH

We work from the assumption that the wealth of an intensive comprehensive literature research would provide us with principal guidelines for the design of both of the game and the evaluation framework.

First I tried to answer the questions:

What are Serious Games?
How serious are they?
How are Serious games of the 21st Century?

Conducting so an Exploratory and Descriptive Research.

Exploratory studies are essential whenever a researcher is breaking new ground, and they can almost always yield new in-sights into a topic for research.

After having acquired a grounded theory about serious games and searching for design and evaluation guidelines, I reviewed an intensive literature about Serious Games Research.
But a general framework were never designed.

Conducting so a Confirmative, Explanatory and Comparative Research at once.

1.3 PROBLEM

How to assess the value of Serious Games?

What does the formal K12 assessment industry think about the use of games?

Where have games developed for Research shown promise regarding games as an assessment tool?

What do game designers think about the concept of assessment in games?

What can game structures tell us about formative assessment, or assessment for learning?

1.4 PURPOSE

From reducing unproductive learning to scaffolding and increasing difficulties are two worlds, we seek the middle, the right individual Adjustment.

In order to integrate adaptivity in our mathematics digital game — seeking the crucial balance between fun and education —, we would investigate the impact and/or the effect of each adaptive variable on the behaviour and emotions of children playing with it (Gameplay, Challenges in Game, Game Environment, Children´s Motivation, Children Skills´Acquisition, ...).

1.5 RESEARCH QUESTIONS

RQ1

What can be observed when a learner plays a serious game and how can this information be used to characterize the individual learner?

RQ1.1

What can a tutor observe when watching a learner playing a serious game?

RQ1.2a

How can this information be used to characterize the individual learner?

RQ1.2b

How can a tutor use the observed information to recognize and rate a skill of a learner?

RQ2

What are changes that need to be applied to a serious game (while playing) to change the difficulty of the tasks based on the Knowledge Space Theory?

RQ3

How would experts apply non-invasive help to a serious game by just observing learners? How can this task be formalized?

For being able to design a system that can behave as a human tutor in the way ZPD is defined, we need to transfer the help-methods given by tutors in direct way to learnars, into help that is applied in a serious game.

The difference between this two cases is, that in games we do not want to interrupt the learner.

Therefore we need to find out a way to apply this help in a non-invasive way.

RQ4

How can a serious game be individualized to each student individually? How can a serious game be automatically adjusted for each individual learner to have just the right amount of challenge for both: learning and game elements ?

RQ5

What is the impact of (auto-applied) adaptivity in serious games in comparison to the help given directly by the human?

1.6 OUTLINE

1. Introduction
2. State of the Art: Serious Games Research
    a) Serious Games
    b) Design Essentials
    c) Research Trends
3. Pilot Study: Bug Game Adaptation
    a) Bug Game Development
    b) My Methodology
4. Evaluation Report
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        ii. Reuse of Results in planned Future Work
        iii. Contributions about Assessment within Games, no need of evaluation, self-evaluation

Part II

STATE OF THE ART: SERIOUS GAMES RESEARCH

2

SERIOUS GAMES

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)

2.1 HISTORY AND EVOLUTION

In general play occupy an important part of most children's leisure time and an important part of our culture as a whole.

In the last twenty years and due to the quick advance in mobile thechnologies, play was replaced by computer games, ranging from play consoles to educational software on mobile devices such as smartphones and tablets.

Therefore developpers have struggled to present a substantial amount of content and context without sacrificing the degree of control game players expect.

But we should never think that serious games are about putting learning courses into a game or as a delivery of formal learning.

The main reason why we play games remains fun.

Otherwise, if we adopt a broad definition of learning like problem solving, creativity, information access, collaboration, innovation, experimentation, and more, we could admit that serious games promote implicit learning.

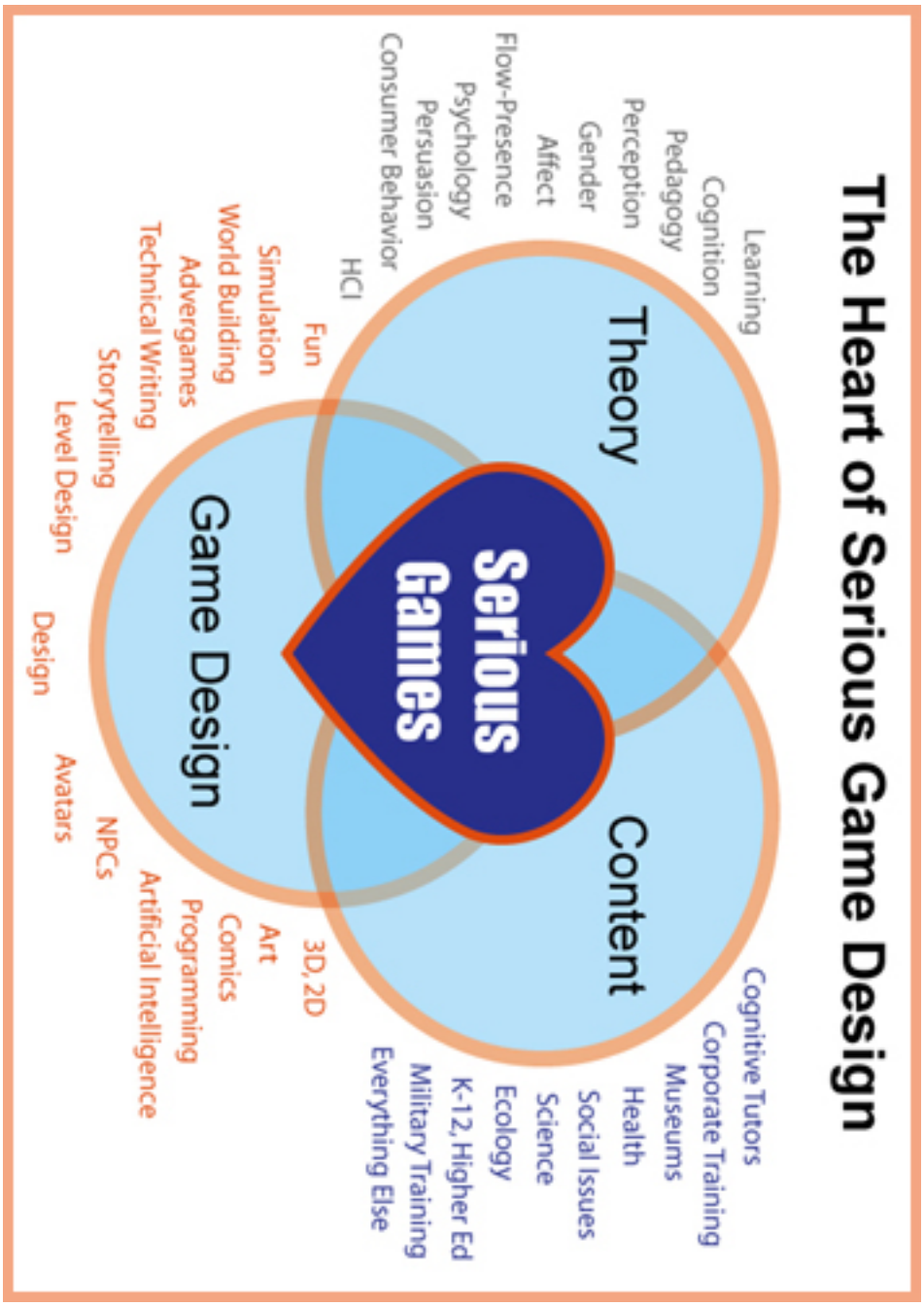


Figure 1: Serious Games — Google

Figure 2: Arts of Serious Games & their operational areas — Göbel [61]

2.2 ARTS OF SERIOUS GAMES

Throughout my literature review, several classifications of serious games can be found that do not meet a general consensus among researchers.

But we can classify serious games in the following seven categories:

- Action Games (interactive gameplay requiring fast reflexes and hand-eye coordination).
- Role-Playing Games (interactive fantasy gameplay requiring planning).
- Strategy Games (requiring analytical thinking, reasoning and planning).
- Adventure Games (interactively experiencing narratives with cognitive/reasoning aspects).
- Simulation Games (replay real or fictitious situations).
- Puzzle Games (matching or constructive puzzles).
- Educational Games (games developed for educational purposes); Games that teach through lively activities combining education with entertainment called Edutainment (Yanhong, Liming & Lifang, 2010).
  This combination transforms the game into an effective tool for educational purposes, with elements such as immediate feedback, interactivity, and challenge (Annetta et al., 2006; Amr, 2007; Yusoff, 2010).

2.3 SERIOUS GAMES BACKGROUND

Next to Fun, Motivation, Engagement, Brain Health and Play itself — Gameplay basics and rules —

A serious game won´t be considered as serious and won´t fulfill an educational goal, if we wouldn´t pedagogically assign the learning content to the gaming experience.

2.3.1 *Motivation, Fun & Engagement*

In the jargon of today's young generation, gameplay rules; Why? Because gameplay motivates, so simple as that.

Serious games can motivate players by providing them with appropriate levels of challenge, curiosity, control, and fantasy.

The motivation is on his turn associated with fun, the great motivator in games, which is the result of the positive feedback players get from a game.

Since we are dealing here with digital educational games, not in general with games;

dare I ask – could we combine fun & learning?

Without being able to define either "fun" or "learning" specifically, can we say anything about the relationship between them.

Does having fun hurt learning, or help it?

Some researchers have looked at this:

- Rose and Nicholl, 1998 admitted that:
  "In simple terms a brain enjoying itself is functioning more efficiently."
  "When we enjoy learning, we learn better."

- Bisson and Luckner, 1996 appreciated that:
  "Enjoyment and fun as part of the learning process are important when learning new tools since the learner is relaxed and motivated and therefore more willing to learn."
  "The role that fun plays with regard to intrinsic motivation in education is twofold. First, intrinsic motivation promotes the desire for recurrence of the experience. Secondly, fun can motivate learners to engage themselves in activities with which they have little or no previous experience."

So fun in the learning process relaxes, motivate and engage in further tasks.

Relaxation enables learners to take things in more easily; motivation enables them to put forth effort without resentment.

Our next big deal is effectively; How can we garantie more gameplay — continuous, appropriate challenge — into the educational process?

2.3.2 *Pedagogical Background*

Games, being the language of young generation children — till they are enrolled first in kindergarten or later in schools — can be useful in enhancing memory capacity, in concentration of attention and in the problem solving strategies of young children, which can indirectly affect their academic achievements.

This encouraged many researchers appealing to embed games within the curriculum and focusing on the need for pedagogical support during gaming as well as during learning, what we normally have.

The seriousness in serious games, as we can see from Figure 3 on page 15, 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.

But games by themselves have been approoved by both educational researchers, experts and game developers as a great potential learning tool, because games invoke intense engagement in learners, encourage active learning or learning by doing, foster collaboration among learners, increase likelihood of knowledge acquisition and knowledge application, enhance understanding of complex and abstract phenomena, and cater to the individual learner's needs.

2.3.3 *Psychological Background*

Developmental psychology provides us with an extensive knowledge and research based on children's development.

I would limit my concentration on two of the main aspects: Brain health and Play itself.

1. To Brain Health, as a pattern;
   Just like a muscle, if used regularly, it can be kept fit.
   A regular play of brain challenging games can contribute to brain health.
   Our brains are good enough at pattern matching and executive

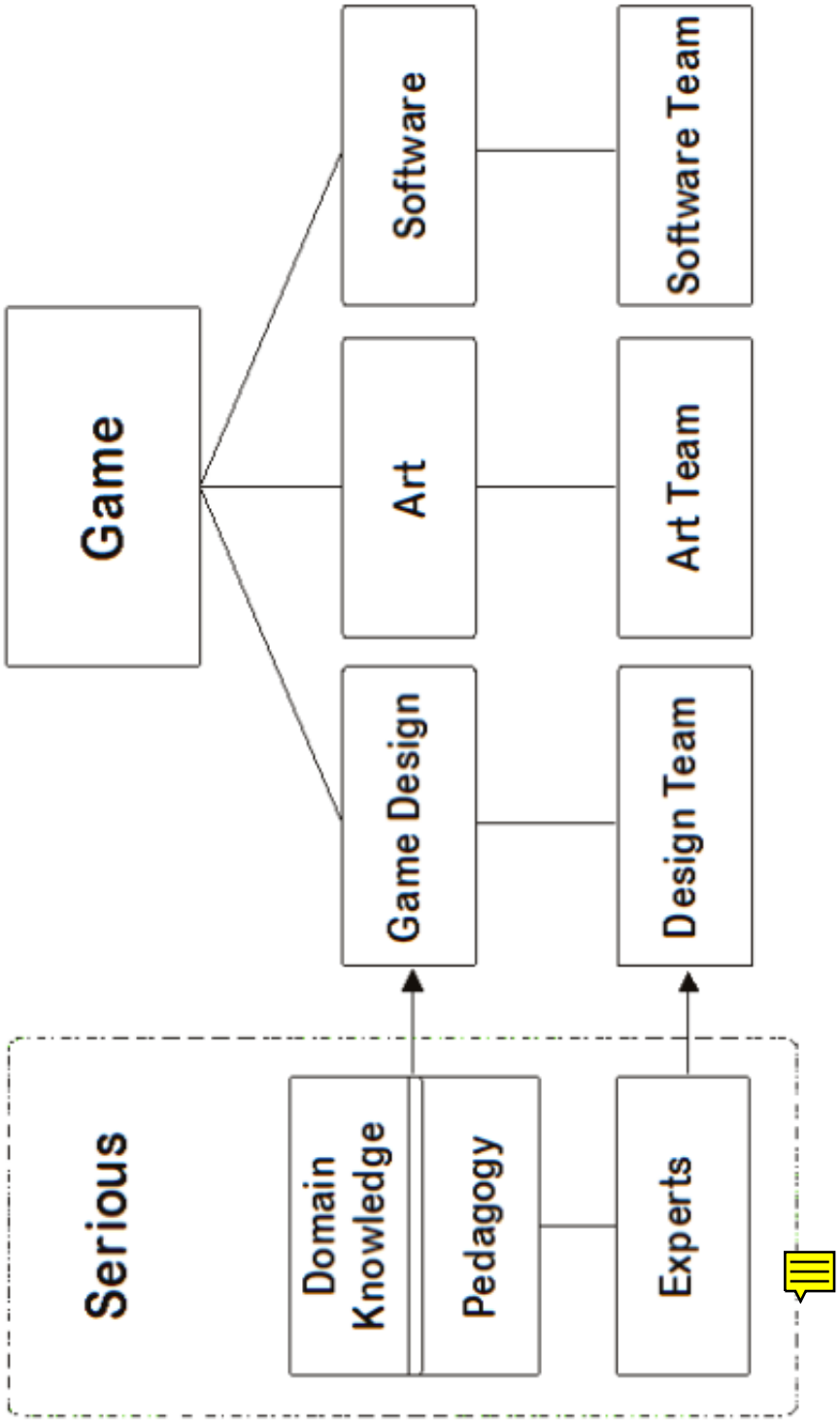


Figure 3: Serious in Game Development — Masuch [121]

monitoring.
The essential goal from the gaming experience is letting us practice what our brains do well and providing support for what our brains do not do well.

"High Score Education: Games, not schools, are teaching kids to think." – Wired Magazine Title Story, 2003

2. To Play, as a powerful mediator for learning;
Early childhood educators know how important play is in children's lives. Play is not only an enjoyable, spontaneous, self-initiated and self-regulated activity of young children, which is relatively risk free and not necessarily goal-oriented. Play is intrinsically motivated: normally children have an internal desire and interest to engage in play, they are actively involved in creating their play and are in control of it.
The toys and gestures with which children play are seen to be significant artefacts from their social and cultural settings — so, in play, children are acquiring the tools and meanings of their culture —
All of the researchers, each on his way, assigned Play a significant role in the growing of children's minds.

- Researchers like (Groos 1898, 1901) have even admitted that play prepares children for adulthood, due to the development of physical and mental capacities that will serve them as adults.

- Others like (Vygotsky 1977, 1978) view play as the most significant leading activity of the early childhood years, what in other terms means that the most significant psychological achievements of the early childhood age occur while children engage in play and this promotes spontaneous learning.

- A German philosopher, (Schiller, 1879), defined play as "the aimless expenditure of exuberant energy" where the Recreation or Relaxation play theory stems from.

- Further more 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.

3

DESIGN ESSENTIALS

More and more serious games researchers, appreciated by the benefit from the child computer interaction and the birth of new interactive technologies, aim to present educational content in a playful way, even to adapt the learning experience to the pedagogical needs of each pupil making from these digital educational games effective teaching tools.

Towards a new Era of gaming and learning experience, many psychological and pedagogical theories have been adopted to the field of serious games, what aid researchers and developers to better understand the cognitive and emotional development of young generation players.

3.1 NOTION OF 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.

Adaptive vs. Generative

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.

A more scientific definition of Adaptivity would be Damir Ismailović [78]´s, as he defines an

"adaptive serious game as a game that implements the Adaptivity approach."

and clarifies this approch as:

"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.

Further Ismailović [78] describes adaptive serious games a system that possesses a special adaptive behavior that helps it to adapt to the ZPD of the learner with the possibility to learn from experience.

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.

3.2 FLOW THEORY

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.

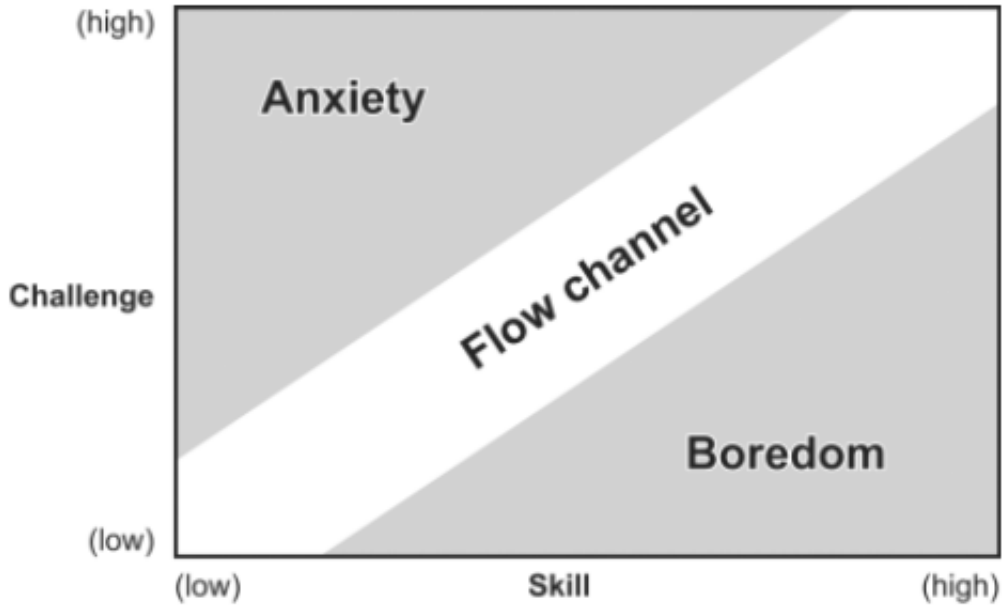


Figure 4: The flow channel of Pomper et al. [144]

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 4 on page 19— 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."[1]

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.

Flow Channel

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.

1 Mihály Csíkszentmihályi; Flow: The Psychology of Optimal Experience; 1990

For this reason a serious game has to be designed in such a way that it constantly adapts the challenge to the skills of the player.

Game designers define the flow channel as the optimal gameplay corridor as shown on Figure 5 on page 21.

Pomper et al. [144] noticed even that:

"When the challenge gets relatively too high, anxiety is the result, whereas boredom results from the players skill level being much higher than needed to overcome the challenges of the game. "

3.3 ASSISSTED PERFORMANCE BY VYGOTSKY

3.3.1 *Zone of Proximal Development*

The socio-cultural notion of proximal development is probably one of the most famous concepts introduced by Vygotsky, a Soviet psychologist.

Initially he used the concept as an index for intellectual potential, arguing that developmental potential cannot be assessed in absolute terms for example by a score on an intelligence test: it should be based on what a child can learn under optimal conditions for example with assistance.

The zone developed into an educational concept.

The zone is a shared activity, collaboratively produced in the interaction between a child and more knowledgeable others – imitation, though not to be confused with copying.

In short terms, Zone of Proximal Development is defined as:

"the difference between what a learner can do without help and what he or she can do with help, the difference between a child´s actual and potential levels of 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).

In technical terms;

"ZPD is the distance between the actual developmental level as determined by independent problem solving and the level of potetial development as determined through problem solving under adult guidance or in collaboration with more capable peers."

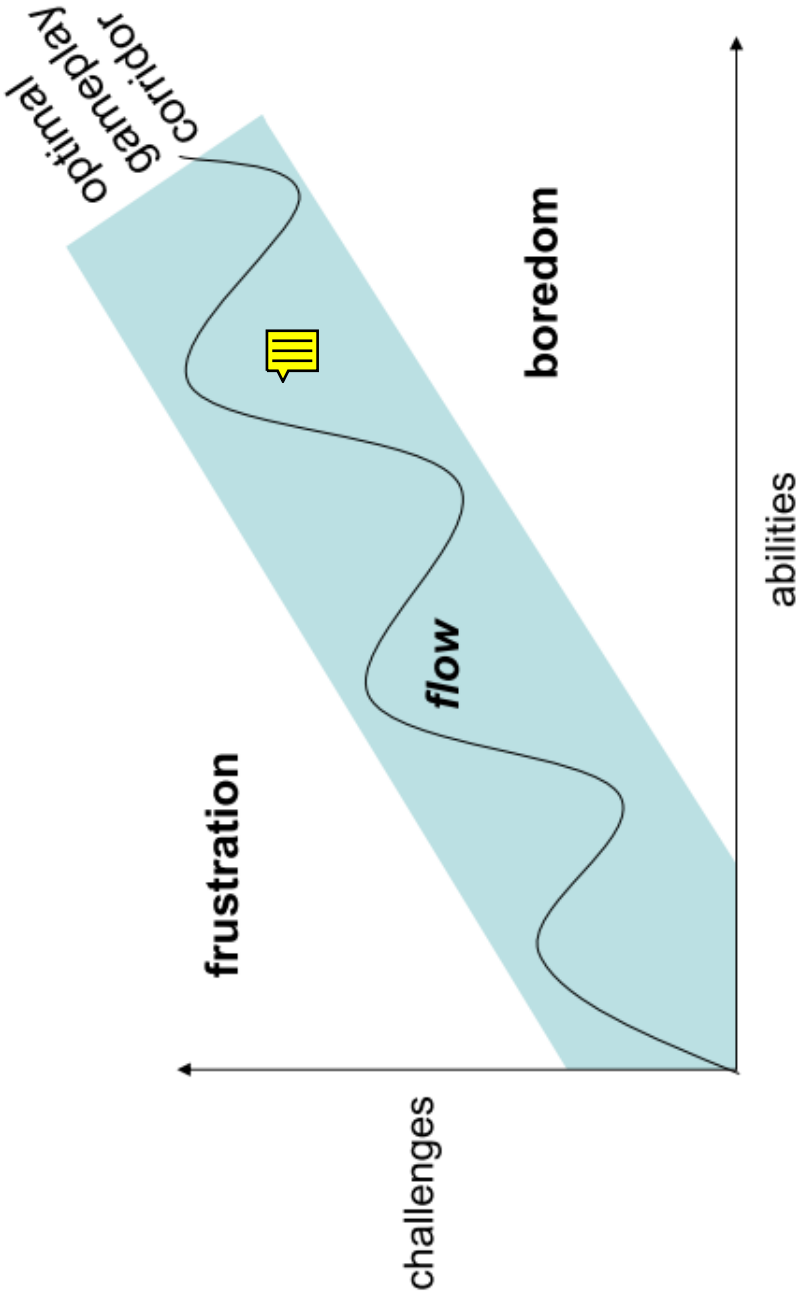


Figure 5: The Flow Theory Masuch [121]

Assisted performance defines what a learner can do with help, with the support of the environment, of others and of the self.

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.

Distinguishing the proximal zone from the developmental level by contrasting assisted versus unassisted performance is of major importance in understanding approaches to education.

It is in the proximal zone that teaching may be defined in terms of learner development.

Vygotsky stated that:

"Teaching is good only when it awakens and rouses to life those functions which are in a stage of maturing, which lie in the zone of proximal development."

Consequently, teaching consists in assisting performance through the ZPD.

Teaching can be said to occur when assistance is offered at points in the ZPD at which performance requires assistance.

3.3.2 *Scaffolding Theory*

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 [193] — in her published Article [2] — 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 admit, as shown on Figure 6 on page 23, that the zone of proximal development defines the bounds where scaffolding is indeed needed.

2 Verenikina, Irina, "Understanding Scaffolding and the ZPD in Educational Research", Faculty of Education, University of Wollongong, NSW, Australia (2004).[193]

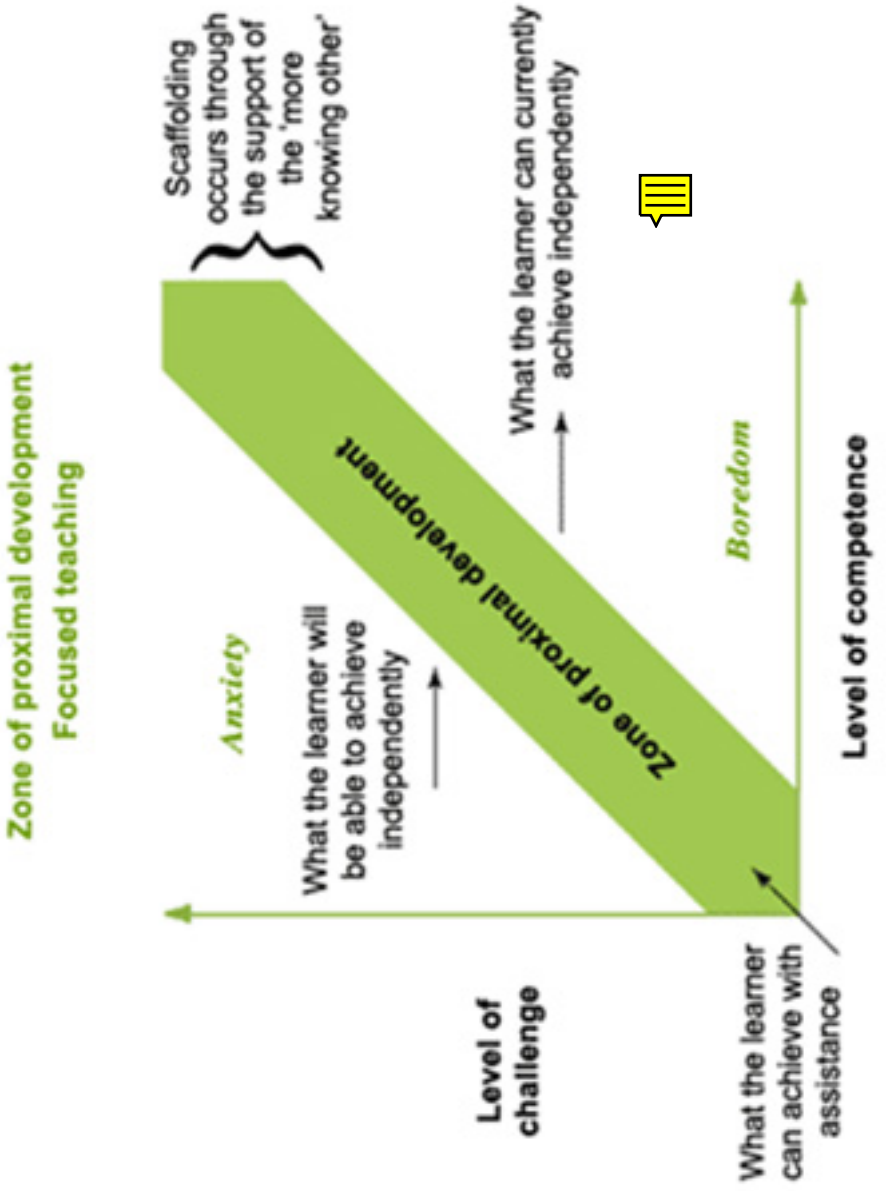


Figure 6: ZPD & Scaffolding towards a better performance. (Google)

Further the Scaffolding theory awares of both engagement & learning since the challenge must be neither too easy (promoting boredom) nor too hard (discouraging continued play).

3.4 ADAPTIVITY APPROACHES

As learning is optimized when the difficulty of the activity lies in the learner's zone of proximal development, where it is a challenge for the learner, but can still be accomplished with scaffolding via hints, suggestions or task and/or event adaptation to suit the learner.

Adaptation Techniques can take many forms like audio tutorial, poupup hints, manipulation of tasks/events difficulties, or even building a complete new game environment.

But The basic idea of the daptivity concept remains to provide the learner with appropriate educational support without corrupting immersion and the flow of the gaming experience.

3.4.1 *Tutor-Adaptivity*

Individual tutoring produces the best learning outcome.

Tutoring systems focus on procedures, constrain students to particular problem solving paths and eventually provide answers to problems instead of letting students attempt solutions and learn from their mistakes.

3.4.2 *Macro-Adaptivity*

Macro Adaptivity: is adaptivity with adjustmens made on the navigationas level.

The primary focus of interest of the macroadaptive approach is the sequencing of learning objects.

Replacing learning goals or changing the level of detail and the delivery system are exemplary factors of macro-adaption.

Observed attributes of the learner include learning styles, motivation, previous knowledge and personality -[78].

3.4.3 *Micro-Adaptivity*

Micro Adaptivity: is adaptivity with adjustmens made on the assesment situation level.

While macro-adaption employs a global view on the learning process, concentrating on the whole curriculum, micro-adaption tries to continually assess the state of the learner, concentrating on tasks and even smaller units -[78].

4

RESEARCH TRENDS

non-empirical or literature review vs. empirical research

The purpose of this section is to provide an overview about research conducted on effects of instructional digital games.

The literature has 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. But little has been published about serious games with mathematical learning content.

The findings revealed that research investigated learning effect of the games from various perspectives by using different research methods.

A number of non-empirical studies were found that examined the effect of instructional games by using the results of reported research to analyze, compare and integrate the findings and reach a conclusion.

The significance of the literature reviews is that they provide an overview about the effect of the games based on reviewing of a relatively large number of articles.

4.1 ASSESSMENT FOR GAMES

As with any other traditional educational intervention, games for learning will need to be evaluated to ensure that they help learning and that they do what we await from them.

In serious games, assessments are used to measure whether or not the product does the job, teaches the required skills, and changes behavior. More important than that, assessment testing should measure whether or not those skills and behaviors transfer to the real world.

Assessment testing will tell the client whether or not the serious game was worth the cost of investment. We should note that instructional designers typically use the term summative evaluations for these assessments. The other form of assessment would be the formative assessment to test the design and behavior of a system as it progresses, generally performed by computer scientists, system designers and

developers.

Why engage in Assessment?

Review of research indicates assessment techniques, both standardized and informal have been, and will remain, an important tool for early childhood professionals.

Assessment methods can be used to screen players´ skills, to assess children performance over the game story, to assist in integrating games with learning intention within the curriculum and daily activities, to evaluate the effectiveness of the game, and/or to provide feedback to parents, clients and developers.

4.2 METHODOLOGY GUIDELINES

According to many researchers in the field of Game-based Learning, we should employ mixed, parallel methods to produce the most convincing body of evidence and to achieve triangulation of data.

Therefore, qualitative case studies were conducted as the dominant paradigm in order to investigate the phenomenon of serious games within its real-life context.

Further quantitative procedures were employed to corroborate and extend the primarily qualitative approach.

Qualitatively, interviews and questionnaires with those who have participated directly in the design and implementation of the gaming solution would be first conducted.
Then in-field observation of the gaming experience should deliver us with needed theories.

Quantitatively, a within-group pretest–posttest comparison or two-groups comparaison would investigate if the children performance level improved through the played serious game.

Which measures should i select, if i would evaluate?

Bowers [15] — in her published article[1] — have dealed with the question of

> "Which measures should i select, if i would evaluate?"

and admitted that one of the most confusing aspects of assessment is choosing which method(s) to use.

1 Bowers, Susan, "Assessing Young Children: Whats Old, Whats New, and Where Are We Headed?" (2007), 5.

Further she grouped Assessment measures into two categories:

Traditional Standardized Tests

1. The first category includes standardized tests and inventories that are available for purchase and used primarily to compare children against developmental norms or to other children.
   Today, hundreds of standardized tests exist, with the majority being designed for use by persons specifically trained in their use and interpretation.
   Studies suggest early childhood professionals tend to choose standardized tests that are already being used by others (Johnson & Beauchamp, 1987).

*Informal Methods like **Observation***

2. The second category consists of informal methods.
   Observations may be obtained from informal methods in a methodical way, but the results are not usually compared to standardized norms or averages.
   Many individuals in early childhood rely on a combination of assessment methods, including some of the common informal methods, as well, as a source of collecting data about young children.

4.2.1 *Standardized Tests and Inventories*

One of the major advantages of standardized tests is that the results can be used to compare a child to developmental norms or to children in similar circumstances.

A norm is an average or series of averages obtained on the sample of children used in developing the test.

A second advantage sometimes cited is the predictive validity of such tests.

That is, children who perform well on standardized tests in the preschool years tend to also perform well on tests in kindergarten and in the early elementary years (Vacc, Vacc, & Fogleman, 1987).

Common tests for preschoolers include the Battelle (Newborg, Stock, & Wnek, 1984), the Child Behavior Checklist (Achenbach, 1992), the DIAL-R (Mardell-Czudnowski & Goldenberg, 1990), the Miller Assessment for Preschoolers (Miller, 1982), the Peabody Developmental Motor Scales (Folio & Fewell, 1984) and the Peabody Picture Vocabulary Test (Dunn & Dunn, 1981). Tests often used with infants include the Bayley Scales of Infant Development (Bayley, 1993), and the Denver

Developmental Screening Test (Frankenburg et al., 1975).

One of the major disadvantages of standardized tests is how to interpret the data obtained. Results from administration of such tests must be considered in comparison to similar children in similar circumstances. Often, this comparison is relatively difficult to achieve.

The predictive validity of standardized tests, that is their ability to forecast achievement in kindergarten, may not be the most important variable we want to know (Pilkington, 1988; Quay & Steele, 1998; Rudner, 1996).

More and more, alternatives to formal tests are being explored, including measures which are thought to be more holistic and developmentally appropriate in their focus and approach.

Standardized tests are accompanied by information regarding their validity and reliability.

Validity information, indicating whether the test really "measures what it is supposed to measure," (Witt, Elliott, Kramer & Gresham, 1994, p. 103) offers teachers the opportunity to evaluate whether the test is appropriate for its intended use.

Reliability information, indicating the test's ability to produce "the same result when repeatedly measuring the same thing," (Witt et al., 1994, p. 95) helps determine a teacher's degree of confidence in the information that will be obtained. Information on both validity and reliability can be found in the manual that accompanies the test when purchased.

4.2.2 *Selecting Informal Methods*

The criteria used for selecting any method should be based on the purpose of the assessment itself.

Questions asked prior to engaging in assessment should include:

- Why do I need this information?
- What is the purpose of my efforts?
- Based on what I need to know, what kind of information will be helpful? Test scores? Written records? Works found in a portfo-

lio?

- How often and when do I need to collect such information, and how can I best assure the information is accurate and valid? In addition, any method used should be selected for its appropriateness for the children on whom it will be used.

- Two important criteria are developmental appropriateness, e.g., "Is it designed for the age of child I'm testing?" and cultural appropriateness, e.g., "Is it relevant to the background and daily circumstances of the child?"

To some extent, any method is only as good as the person performing it.

Thus, assessments are most appropriate when every effort has been made to insure objectivity (Salvia & Ysseldyke, 1995).

Objectivity refers to the process of examining a child or event without pre-formed ideas about outcome. When we are objective we report only the facts, and, in turn, interpret those facts based only on what was observed, rather than feelings or attitudes about the child.

An innovative method is play-based assessment, which evaluates children's developmental skills and their social interactions, learning styles and behaviors through play (Lowenthal, 1997) - [15].

4.3 CHALLENGE

Law and Rust-kickmeier [108] — through the Elektra project — have admitted that:

"Three major challenges for developing and evaluating immersive digital educational games (DEGs) are identified, including:

1. improving adaptive technologies, especially digital storytelling, to shape learning experience;

2. providing technological approaches to reduce developments costs for DEGs, and

3. developing robust evaluation methodologies for DEGs.

4.4 AGREEMENT

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.

To this issue; Researchers have agreed that:

- "The most gaming studies focus on learning conceptually — concepts like reasoning, creativity, system understanding and decision making —, which does not demand special knowledge of subject areas." - [87]

- "The nature of games promotes several vital skills for deep learning, 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)." - [76]

- "An extensive body of research demonstrates the positive effects of digital games on child and adolescent players' learning (Blumberg & Ismailer, 2009)." - [76]

- "Serious games are an effective teaching tool that involve 36 learning principles, but not just by virtue of being a game." - [56]

- "The use of information visualization systems, interactive techniques and multimedia tools in teaching and learning experiences tends to be effective.
  This statement is supported by the fact that these tools can be effective in improving students' learning and data retention for 90% of learners when they verbalize something and then implement it ..." - [47]

- "Contemporary research indicates that educational games have the potential to improve learning (Srinivasan, Butler-Purry & Pedersen, 2008) and to increase the likelihood that the desired

learning outcomes will be achieved (Pivec & Kearney, 2007)."

- "More specifically, educational games can improve learning because they:
  - increase motivation (Garris, Ahlers & Driskell, 2002; Lee & Peng, 2006; Graesser, Chipman, Leeming & Biedenbach, 2009),
  - create cognitive conflict (Chen, Lien, Annetta & Lu, 2010),
  - can improve and enhance visual-spatial perception ability (Greenfield, Brannon & Lohr, 1994; Lee & Peng, 2006),
  - can generate various competencies (such as motor, cognitive, emotional, social, personal, etc.) (Kretschmann, 2010),
  - can stimulate intensive mental engagement (Prensky, 2001), and
  - create conditions for better memory retention (Oblinger, 2004; Lee & Peng, 2006)." - [137]

- "Considering children's natural love for playing games, the growing availability of electronic media, and the fact that children spend a great deal of time interacting with electronic media (Fisch, Lesh, & Motoki, 2009), the educational value of digital games is very clear." - [137]

- "The most successful and the most common form of educational games are the mini games targeting at preschool age and primary education level children.
  These games attempt to help young children to obtain basic skills such as numbers, letters, simple maths, and reading, offering entertainment and instruction for their target audience." - [96]

- "The findings of empirical studies revealed that instructional games promoted learners' attention (Yip & Kwan, 2006), state of flow (Kiili, 2005b), motivation (Rosas et al., 2003), delayed retention (Cameron & Dwyer, 2005), mathematics performance (Ke & Grabowski, 2007; Lopez-Moreto & Lopez, 2007; Shaffer, 1997), knowledge transfer (Shaffer, 2006), decision making (Corsi

et al., 2006), expert behavior development (VanDeventer & White, 2002), and spatial skills and brain oscillation (Natale, 2002).
In addition, using games created dynamic (Rosas et al., 2003) and collaborative (Squire, Giovanetto, Devane, & Durga, 2005) learning environments which positively affected learning." - [88]

- "By administering external tests, teachers may lose much of the value of the games since learners are already inherently demonstrating their knowledge and skills by interactions during gameplay.
Assessments embedded into games will, in addition, reduce the often artificial separation between performance and assessment in school (Reeves & Okey, 1996).
Each of these approaches has shown that students are learning in the gaming environment." - Underwood et al. [189]

4.5 LIMITATIONS

Serious games are pedagogical multimedia products made to help learners develop specific competencies.
Their use has proven to be promising in many domains, but is at present restricted by the time consuming and costly nature of the developing process.
When developing Serious Games for academic purposes, not only is there a budgetary challenge, but there is also the challenge of integrating enough educational value without sacrificing the fun characteristics, admitted Meyer [126].

Law and Rust-kickmeier [108]have seen the integration of external resources (e.g., learning media) with a game engine into a coherent and immersive game environment as difficult.
Since the development and application of immersive DEGs is still at an early stage, to date no appropriate methodologies exist which enable an effective integration of existing learning resources and their (re)use in DEGs.
Hence, it is deemed critical to analyze the technological and didactic demands and mutual dependencies between learning resources, learning activities, pedagogical models, and narrative game engines.
An approach of resource harmonization, resource symbolization, and ontological resource description, should also be established.

- Cost & Time

The development of competitive DEGs is cost-intensive, and the markets are narrow because DEGs may relate to limited age groups or specific curricula.
Thus, the integration of existing learning resources is a crucial aspect of efficient and cost- effective learning design and game development. Law and Rust-kickmeier [108]

- Intervening Variables
  - "With respect to the relation to the variable of gender and the variable the financial status of the family and the variable of the parents´ educational background and the variable of the parents´ occupation point out to slight differences in the achievement rate of the students." - [28]
  - "As Squire (2003) discovered, bringing a computer game into classrooms may raise as many issues as it solves.
    * First, playing games does not appeal to every student.
    * Second, students may be distracted by game-playing, and thus, not achieving the learning goals (Miller, Lehman, & Koedinger, 1999).
    * Further, students may fail to extract intended knowledge from a complicated gaming environment (Squire, 2003).
    * Finally, game design researchers (Smith & Mann, 2002) are worried that making games where the objective is to facilitate students' learning will risk sacrificing the game part along the way." - [87]

4.6 SKEPTICISM

The contradicting views of the literature review, the existence of relatively few empirical studies in the reviews, and the cited methodological flaws in the empirical studies necessitate further rigorous empirical study to help educators and instructional designers reach better conclusions about the effects of instructional games so that they may better understand, implement, and facilitate the games in classroom setting.

As suggested by Van Eck (2006), instructional games would likely experience widespread development and use if persuasive examples of empirical studies could show the enhancement of learning by using instructional games.

"Skeptics toward game-based learning contend that the effectiveness of computer games on learning is still a mystery." - [87]

Several major reviews on educational games indicated no clear causal relationship between academic performance and the use of computer games.

"According to Hodgson, Man & Leung (2010), the wisdom of using digital games for learning is debatable, because games are commonly perceived as tools for having fun. Although games can be effective learning environments, not all games are effective, nor are all games educational and beneficial for all learners or for all learning outcomes (Oblinger, 2006)." - [137]

"A common skepticism on using computer games for learning purposes lies in the lack of an empirically-grounded framework for integrating computer game into classrooms." - [87]

4.7 RECOMMENDATIONS FOR OUR CASE STUDY

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 [149] 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.

Meyer [126] 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.

McCue [123]

Part III

PILOT STUDY: BUG GAME ADAPTATION

5

BUG GAME

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!

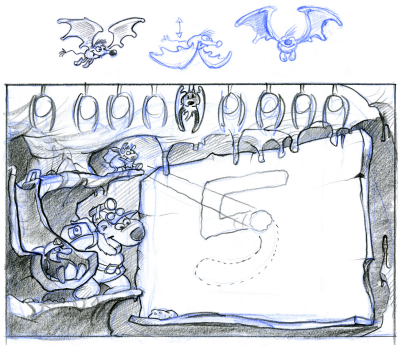
5.1 GAME DEVELOPMENT

In DANCE Research Group, we're responsible for designing serious educational iPad games for children. Some of these games are categorized to join the "E&P" series of games. E&P are two actors present in these games and they're responsible for children guidance, motivation and audio feedback.

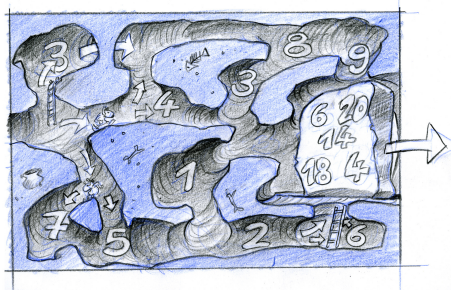
The games were designed to reinforce academic standards for mathematics and target a variety of math skills, such as recognition of numbers, the right way to write them, making addition/substraction until 10, 15 or 20, geometry and so on.

This game consists of 5 mini games, an intro game () and an award game (Ufos). These 5 mini games on Figure 7 on page 40 are the "Rope Game", the "Bug Game", the "Math Labyrinth Game", the "Torch-Light Game" and the "Magnet Game".

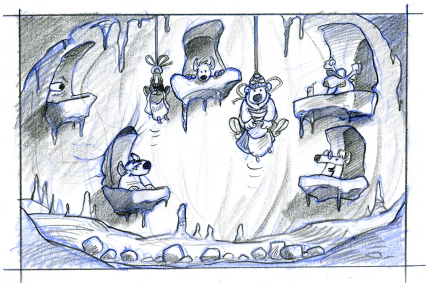
There are also two main parts that are designed in parallel to these mini games. The first part is a game framework that is responsible for putting all the five mini games together with the intro and the bonus games to represent the whole big game. The second part, and the most important, is the adaptivity model for the big game. This model is responsible for detecting the player's performance in each mini game and accordingly increases or decreases the game level.



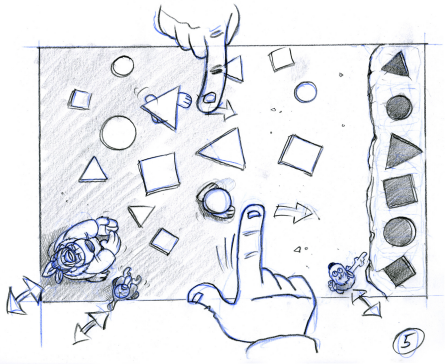
(a) Flash Game



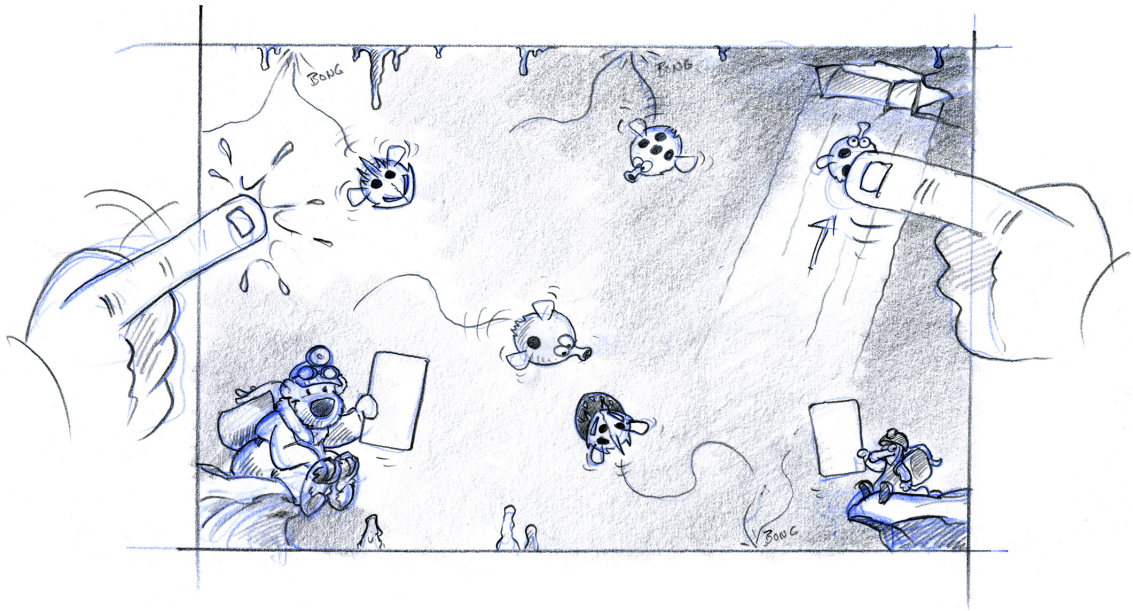
(b) Labyrinth Game



(c) Rope Game



(d) Magnet Game



(e) Bug Game (Case Study)

Figure 7: Copyright © Jan Birck - Zeichner der eingesetzten Skizzen - http://www.janbirck.de/

Our game would mediate communication through the main characters in the game, support activity since the child should interact with the iPad and encourage productive learning through mathematical tasks.

For the further of the Study, we focus on the Bug Game, Figure 7e on page 40, with the **most manipulable variables**.

First, the non adaptive game had Gamelog and score keeping and employed progressive difficulty levels – harder problems were presented at the higher levels of the game.

5.1.1 *Bug Game Story*

We worked in Group, Farah George [45] was the developer of the first prototype.

I would present you the game story with his words.

The Bug Game is a serious game used for learning. It should teach the 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 Bug Game has to be developed with a lot of features and behaviors. Examples of these features are the bugs movement and animations as well as their behavior when they meet each other.

Moreover, the game should have many adaptable elements that can be changed easily.

Consequently, by integrating it with the adaptivity model, the game should change its behavior and difficulty according to the child's performance.

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 throwing 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.

First Settings for the non-adaptive mode!

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.

5.1.1.1 *Scenarios:*

- **Scenario A: Saving a Good Bug**
  A child plays the bug game.
  He observes E&P on both sides of the screen.
  E. holds a card with the number 4 on it which means that each bug with the number 4 is a good bug.
  The child sees a bug with the number 4, he drags it or sends it

to the cave and saves it.

- **Scenario B: Interacting with a Bad Bug**
  A bug with a number different than the ones held by E&P means that its a bad bug.
  The child hits the bug, the bug is splashed and killed.
  He drags a bad bug to the cave and saves it or he fails to drag it far from the cave, the game is over and the child loses.

- **Scenario C: Behavior of Bad Bugs**
  When a bad bug comes near a good one and the child fails to move them away from each other, they collide, the bad bug opens its mouth and eats the good bug.
  If two bad bugs come near each other and the child fails to move them away from each other, they collide, the 2 bugs duplicate and become 4 bugs.

- **Scenario D: Winning and Losing the Game**
  When the child saves all the good bugs or more than half of them, he wins the game.
  When he saves only one bad bug or fails to save more than half the good bugs, the game is over and he loses.

5.1.1.2 *Functional Requirements:*

- **Good Bugs and Bad Bugs**
  This game consists of two kinds of bugs, good and bad bugs.
  A bug should hold a certain number of dots which are responsible for the teaching process.
  Bugs in this game should be moving through all parts of the screen, rotating according to the direction of motion and should be animated in different game situations. A specific number of bugs should enter the screen with a pre-determined rate. A player should be able to hit a bug or drag any bug through any place on the screen. He should be able to save good or bad bugs by letting them exit the cave and he can kill bad bugs by hitting them by his finger. When a good bug and a bad bug meet each other, the bad bug should eat the good bug. When two bad bugs meet each other, they should duplicate to become 4 bugs.

- **Multitouch**
  The game should be a multitouch game so that more than one player can play together at the same time or a player can play

with both his hands.

The mini-game should be adaptable!

- **Adaptability**
  This game should be adaptable (not adaptive).
  The game should provide a sort of different easy and advanced behaviors to what is called the adaptive model.
  This model is to decide which behavior should be changed, and when according to the player's performance during the game.

- **E&P**
  Two main actors sitting on both sides of the screen, E&P.
  One of them or both should be holding the number of dots that are carried by the good bugs.
  They should be animated in different game situations.
  They should be talking to the player, guiding and motivating him during the game.

First Settings that would change after the evaluation process!

- **Winning and Losing**
  A score of the game, which is equal to the number of saved good bugs, should be displayed for the player on the screen.
  The game should tell the player one of 4 situations that end the game.
  First, when one bad bug exits the cave, the game is over and the player loses.
  Second, when all good bugs are saved, the player wins the game with full score.
  The third situation is that when no more good bugs are there and the score is less than half the full score, the player loses the game.
  Finally, when no more good bugs are there and the score is more than or equal half the full score, the player wins the game.

5.1.1.3 *Nonfunctional Requirements:*

- **Usability**
  Usability is the ease with which a user can interact and operate with the system.
  Since this game is for children, it should be more usable to allow the child to play understand its purpose and play it easily.
  Moreover, usability should be measured by the amount of time the player should wait to interact with the system and observe the result of this interaction.
  For example, killing a bug shouldn't take more than 1 second.

- **Reliability**
  Reliability is an important factor of software quality.
  This game has to be reliable meaning that it should run continuously for 1 hour or until the game is over without crashing.

- **Performance**
  A major factor in determining the overall productivity of a system, performance is primarily tied to availability, throughput and response time.
  This game should have a good performance. During the game, there are many good and bad bugs on the screen and many others entering the screen. The game should handle the motion and the behavior of all of them. Also, the game should guarantee the player a quick response for his interaction with it.
  He should only wait for 2-3 seconds maximum in some cases depending on the animations running before the actual result.
  This is a similar idea to usability mentioned in subsection 3.4.1 but from the system perspective rather than the player's perspective.
  Morever, the performance can be measured with the frame-rate. So the game should have a minimal frame-rate about 30fps in some cases, and average frame-rate should be between 40 and 60 frames per second (fps).

- **Supportability & Extendability**
  The mini-game should be adaptable!
  Supportability is all the actions related to the inherent quality of the system.
  To deal with fast changing development requirements, the system has to be extensible.
  This extensibility could be considered as a part of supportability.
  The game should be able to easily integrate current and future technologies without major modifications of the existing system.
  The game has a lot of elements to be adapted and can be used by any other system.
  An external adaptivity model can be easily connected and integrated with the game such that the game behavior is changed depending on the player's performance.

- **Implementation Requirements**
  Implementation requirements are constraints on the implementation of our target system which specify tools and hardware platforms to be used.
  This game is designed only for iPad and cannot be run on any other iOS device.
  Also, it is restricted that the development of this game is done

using Cocos2d framework which is one of the most important and popular frameworks for iOS development.

5.2 ADAPTIVITY MODEL

5.2.1 *Adaptive Approach*

The game structure offers the option to include adaptivity on different levels.

The use of adaptivity on the macro level was skipped in order to include a higher level of control -[78].

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. This increases the flow experience (Sweetser & Wyeth, 2005).

The idea of adaptivity through Aptitude-Treatment interaction approach by dynamically generating 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.

Since the main focus of the game lies in practicing skills learned at school rather than teaching new content, the need for complex feedback is relatively low and therefore was skipped for the time being.

The same applies to the Constructivistic-Collaborative adaptive approach.
If practical use of the game shows the need for it, adaptive feedback can relatively easily be added retrospectively -[78].

The current implementation of the game focuses on the implementation of adaptivity on the micro level.

On the level of the particular task (the mini-game) the difficulty is adjusted to the progress the child makes while playing.

Additionally game data is stored and used for the setup of the next mini-game.

Dynamic difficulty adjustment can be achieved through two different approaches:

- Game Aspects: all aspects which are not directly linked with the learning content itself but rather with attributes mainly influencing the gaming experience: parameters such as speed or number and size of the elements presented.

- Learning Content Aspects: the actual learning objectives, the exercises presented, such as how many tokens to count, or what numbers to calculate.
  The concept of easier and harder Learning Contents and the influence of their order of presentation is based on the Knowledge Space Theory -[78].

The Knowledge Space Theory first introduced by Doignon and Falmagne (1985) is a structural approach towards human knowledge gaining.
Knowledge Spaces are based on competencies and are somehow connected with each other and dependent on each other.
The theory categorizes problems, learning objects and skills -[83].

Learning objects are assigned to a set of skills which are relevant for solving the problems.
Skill functions can be formulated based on the subset of skills sufficient for a particular problem. Some skills are prerequisites for others.
This leads to a structure of competence, where each skill is assigned to a collection of subsets of skills.
Acquiring one skill requires mastering of all skills of at least one of those underlying subsets of skills -[5].

To sort the Learning Content by difficulty the Bavarian first grade curriculum was used as a point of reference (Staatsinstitut für Schulqualität und Bildungsforschung München, 2000).

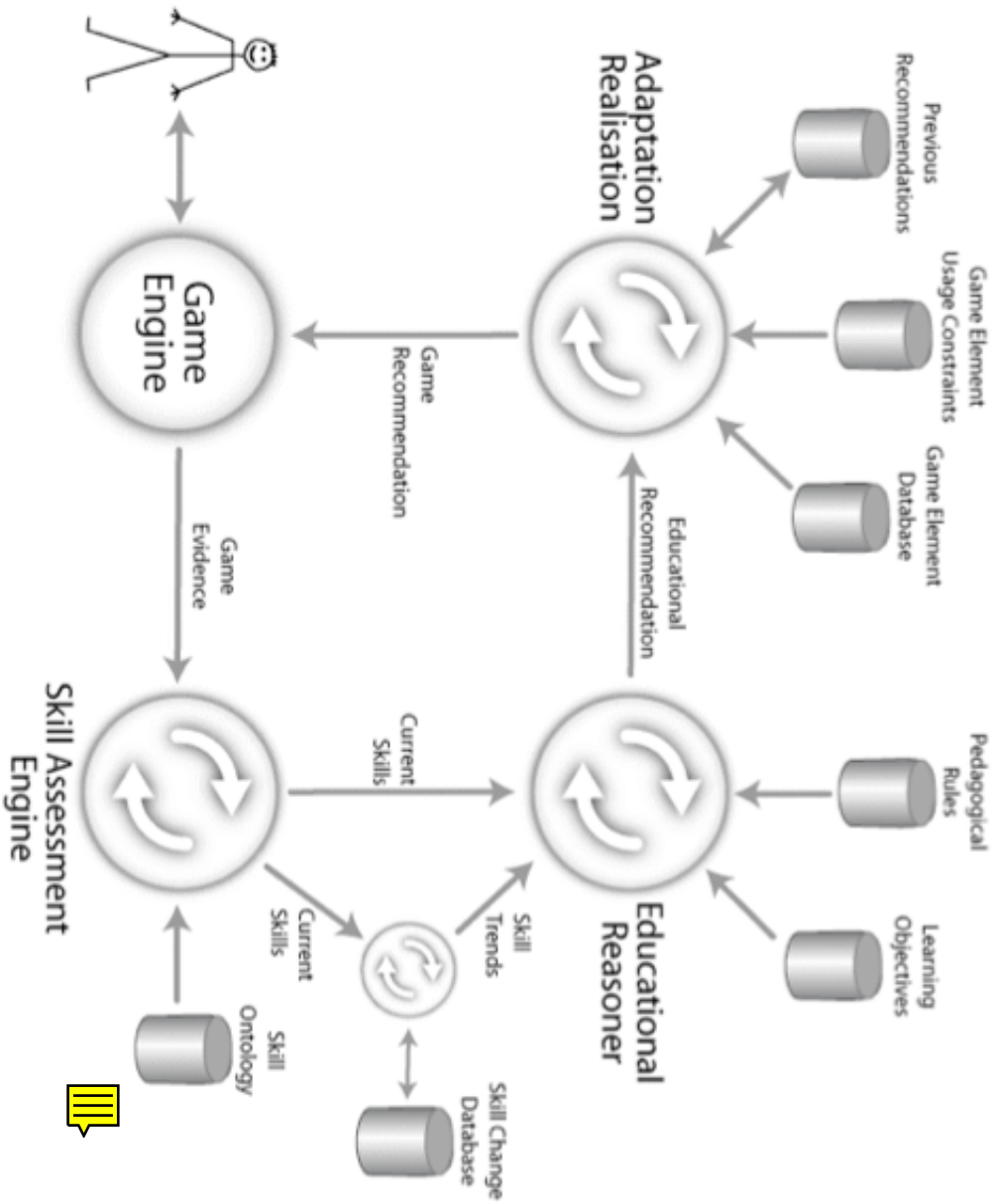


Figure 8: Elektra Architecture of Micro-Adaptivity Albert et al. [3]

5.2.2 *Model*

As i wrote this thesis, the work progresses, and our Models are constantly changing and would, at the latest, in few months in Damir Ismailović´s ongoing Ph.D. [79] explicitly presented and discussed.

I would present you here the principle of our game architecture, as shown on Figure 8 on page 48, from the sight of the researchers of the ELEKTRA Project, an european interactive tutorial game for educational purposes[1].

This work was cited by many Serious Games Reserchers, because it was the first of his art that evoqued and adopted the adaptive approach in digital games[2].

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 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.

The scope of this thesis redefined!

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.

1 http://www.elektra-project.org/

2 [3, 2]; [28, 29]; [111, 108, 109, 110],;[11, 10, 12, 13]; [124]; [5]; [83, 80, 81, 79, 78]; [91, 94**? ?** , 95**? ? ?** , 96, 90**?** , 92, 93, 89]; [126]; [155]; [101]; [141, 142, 143, 140]; [131]; [100]; [60].

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 Ismailović 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)

6 MY METHODOLOGY

6.1 CONTEXT OF THE STUDY

Relying on these two statements;

"Software can be made age appropriate even for children as young as three or four (NAEYC 1996)." - [194]

&

"Digital devices are the perfect augment. Digital devices can be programmed to "say" or do anything you want and can execute reliably and repeatedly. They will remember arbitrary facts, and respond appropriately to the input you give them every time. However, they are not particularly good at making decisions or detecting the nuances of a conversation." - [149]

We are going to develop a game aimed at small culturally specific user populations respecting "the state of the art guidelines" to designing serious games.

6.1.1 *Social*

Preschool children (4 to 8 years old)

When designing software for young children, we should focus on a specific age group and try to establish a user profile of typical preschool gamer including their sociocognitive development, development of play and the cultural aspects of development, because children of different ages have vastly different preferences, development factors and levels of skills.

Although the most research has been done on games for older children and no guidelines exist, that distinguish between different age groups, what makes our task as developers and reserchers more complex, we focus on the 4 to 8 age group for the following reasons:

- Each child is unique and has an individual growth and development pattern, personality, temperament, learning style and background.
  The child's age can therefore be regarded as only a rough index of developmental status.

- At this age, children start their schooling experience and appropriate products can enhance school readiness and support the acquisition of cognitive skills such as reading, writing and story construction.

- Fine motor skills and hand-eye coordination are, at this age, adequately developed to use digital devices.

6.1.2 *Technical*

Promising contributions are seen in the field of Human Computer Interfaces and multimodal interfaces, addressing the potential of increased dimensions of multi-touch displays on mobile devices and natural, gesture-based interaction and control of computers and applications.

Hardware & Software used; Tablet Touch iPad & mobile learning with adaptivity

In the last few years digital educational games have gained attention as a tool for facilitating learning in different sectors of society including but not limited to military, health, and education.

A number of factors have made Digital Educational Games´ attractive learning tools.

The advancement of technology has made it possible to play games on simple platforms such as mobile devices, provided children with opportunities for engaging in activities associated with computers and since the use of new technological and learning methods has prooved an improvement of the learning process, a wide range of software has been designed with young children in mind.

With an iPad application, we're reaching a specific user demographic, but if the demographic makes sense, this is an attractive platform because of its mobility, crisp graphics, gestural interface, and other unique interface elements.

The iPad has quickly become a prime platform for advergames and persuasive games, and more robust serious games and simulations are being developed for it.

The gestural interface and accelerometer open the door for innovative new applications. Because of its handheld nature, certain serious games and simulations can seem even more immersive.

6.2 MY EVALUATION FRAMEWORK

6.2.1 *Rigor of the Study*

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 an evaluation.

6.2.2 *Restatement of the objectives and Research Questions of the Study*

Our Study doesn´t aim at contributing to the understanding and measuring whether digital games can be considered suitable and effective tools for enhancing learning.

Then this has been already discussed and ensured through the contributions of other researchers on Serious Games during the last decade.

"Backwards Adjustment of Micro-Adaptivity"

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.

6.2.3 *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

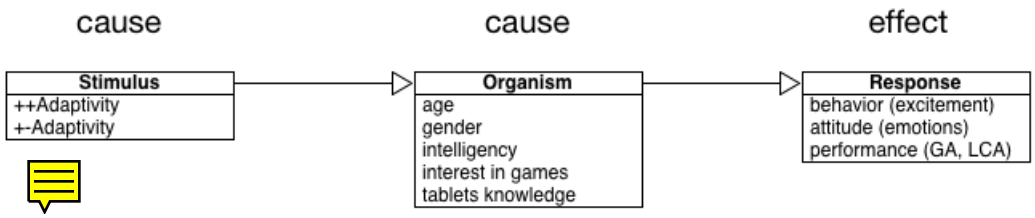


Figure 9: Cause-Cause-Effect

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 10 on page 55 and Figure 11 on page 56.

6.2.4 *Evaluation Design*

Implementation & Process Evaluation

There are a lot of different definitions of evaluation.

Here is one of the best, because it touches on the most important aspects of evaluation:

"Evaluation is a collection of methods, skills and sensitivities necessary to determine whether a human service is needed and likely

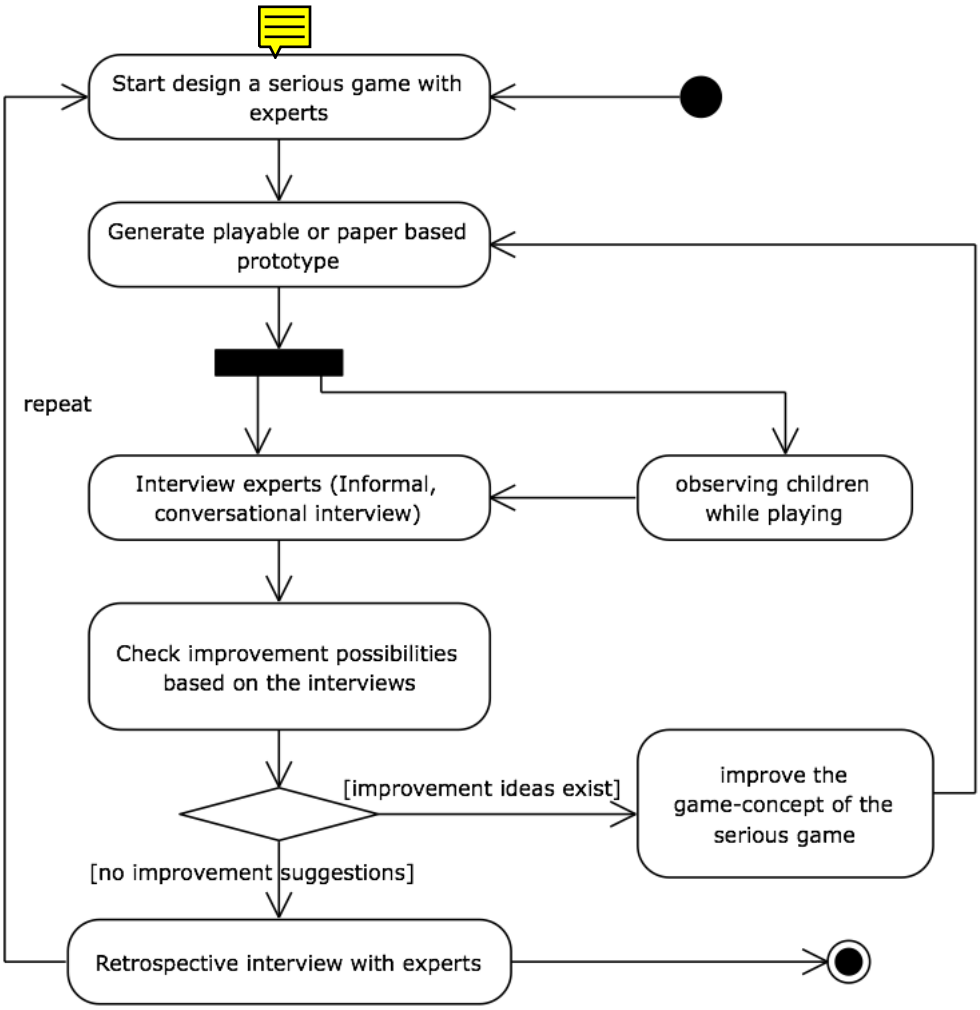


Figure 10: Study Overview

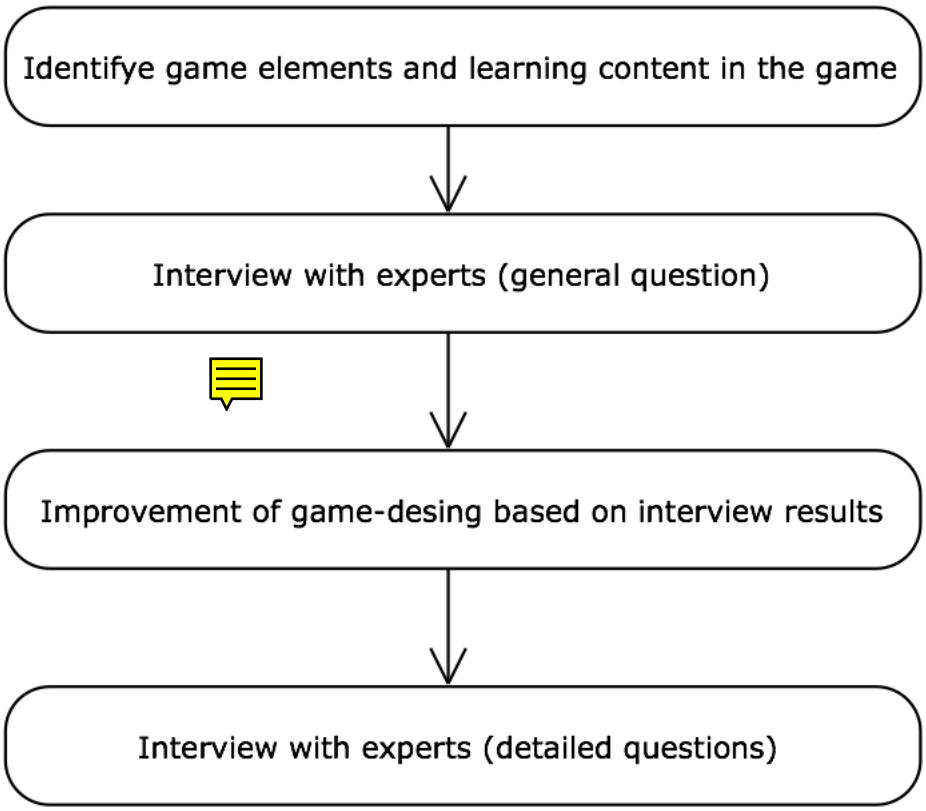


Figure 11: Study Overview 2

to be used, whether it is conducted as planned, and whether the human service actually does help people" (Posavac and Carey, 1980, p.6).

This definition encompasses the two main types of evaluation: process and summative.

The evaluative purpose of social work research actually encompasses all three of the preceding purposes namely exploration, description, and explanation of the encountered social phenomena.

Since we would evaluate a game prototype, it is unrealistic to aim to determine the learning effectiveness through the game. And since we are at a phase, when we would change the game from non-adaptive to adaptive and more individual in order to increase the learning experience and to make the game events more challenging.

We would focus more specific on the effect of micro adaptive interventions such as cognitive hints related to the skill assessment of the learner and motivational hints related to the motivational assessment of the learner.

Since our game would be adaptive, depending on who is playing and how much skills does she/he have, I have chosen to adopt the qualitative approach in my evaluation to investigate the immediate and long term impact of the dynamic scaffolding adjustments made on the skills and events levels of the inspected game.

Due to the nature of serious games, generally, and their psychological and pedagogical backgrounds, and especially our game with mathematical content, the study would answer the questions related to the pedagogical agents incorporated in the gaming experience.

Why have I choosed the Qualitative Approach?

Rubin and Babbie [159] admitted, in this issue, that:

"we do not need to choose one camp or the other. Each approach is useful and legitimate.
Each makes its unique contribution to inquiry.
Each has its own advantages and disadvantages.
Each is a set of tools, not an ideology.
Researchers need to match the tools they use with the research questions and conditions they face using quantitative methods for some studies, qualitative methods for others, and both methods in combination for still others."

Whether we should emphasize qualitative or quantitative research methods depend on the conditions and purposes of our inquiry.

Qualitative methods may be more suitable when flexibility and deeper understanding are required to study a new phenomenon about which we know very little, or when we seek to gain insight into the subjective meanings of complex phenomena to advance our conceptualization of them and build theory that can be tested in future studies.

6.2.5 *Site Selector & Participants Selection*

We have chosen to visit children at their home, play yard and even at kindergarten.

Our sample was not great in comparaison to other studies, because we search not to test the effectiveness of our serious game in teaching mathematical basics (recognizing numbers, counting in the case of the Bug Game).

The ages of the participants varied from 3 to 8 years. Their math abilities were classified into four levels – advanced, proficient, basic, and below basic based on the estimations of their parents and/or teachers.

Participants were questioned on their prior gaming experience and even more precisely, their experience with tablets (in our case Apple´s iPad).

For all, even if they had experience with these devices or not, we trained them the basic skills, in order to better wield the iPad.

Then we hield one orientation session to familiarize them with the gaming environment and were trained them to do think-aloud;

"a strategy in which participants verbalize aloud while interacting with computer games, thus modeling the cognitive and affective processes of game-playing." - [87]

6.2.6 *Data Collection instruments*

As Plato already ensured:

"*Watch a man at play for an hour and you can learn more about him than in talking to him for a year*" (Plato, 427-348 v.Chr.).

The best way to collect information about the player (e.g. a child playing a serious game) is to observe him playing. - [78]

Observational studies are widespread used, especially among academics.

They don't require an experimental design and allow greater understanding of the pathways to change (tests conceptual framework), but confounding factors (understanding emotions) would be difficult to rule out.

In our case, we would observe childrens´behaviors, verbal and nonverbal, facial expressions during gameplay and simulatanely record them for later analysis through pedagogues, psychologues and experts.

6.2.6.1 *Video Material Permission from Parents*

Our study would be videotaped, since we rely on the experts´ interpretation. Therefor participants and their parents have been told that:

- the play sessions will be videotaped;
- the cassettes will be coded so that no personally identifying information is visible on them;
- they will be kept in a secure place (Chair for Applied Software Engineering, TUM);
- they will be viewed only for research purposes;
- they will be erased after they are transcribed or coded.

Part IV

EVALUATION REPORT

7 EVALUATION STUDY BUG GAME

7.1 EVALUATION PROCESS

It would be an iterative process, as mentionned in our logic model on Figure 10 on page 55, since we would over and over adjust the game by integrating the collected results.

7.1.0.2 *Phase I: Experts´Interviews (RQs)*

We conducted personal, semi-structered and open interviews with experts at once to answer our Research Questions (1-5).

The questions varied from general statements about serious games until specific questions related to the adaptive mode of our game.

7.1.0.3 *Phase II: Play Observation (Game Situations)*

With the aid of experts, we were able to define different Levels of challenge in the game related to whose playing it.

We built Game Situations, (Easy, Medium, challenging and Difficult), and according to the age of the player and his mathematical knowledge level, we tried to assign him/her the right challenging level / Game Situation accomodated to his / her needs and abilities.

A group of helpers were mobilised to measure the impact of each proposed level on a group of children (Enjoyment or annoyment), a second one to measure the time taken for each level or until the first disenjoyment/angryness per child.

As intended, we would extract the effective time before activating the adaptive mode and the best time to switch between levels predefined from the experts.

7.2 EXPERTS´ INTERVIEWS

The aim of the interviews with experts is to gain insight into their opinion about how freely could we adapt the game, the settings that

NAME	SECTOR
Dr. Pohl (Psy)	Psychology
Frau Bartl (GS)	Game Story & Pedagogy
Guido (Ped)	Pedagogy
Dennis (GD)	Game Design

Table 1: Intervieews

are needed for each child and for each game situation.

The interviewees (Table 1 on page 64) ranged from Psychologues, Pedagogues, Math Teachers to game designers from the Chair for Applied Software Engineering - TUM. All of the interviewees had a clear and detailed understanding of both scenarios and requirements of the game.

We contacted the experts one week earlier, send them the scenarios and requirements of the game being evaluated and the game itself, so that they could try and generate first impressions and ideas.

Before the interview started the purpose of this research was explained. Subsequently, consent was asked for recording the interview and each of the experts have had the game in front of him to simulate the situations discussed.

7.2.1 *Interviews*

RQs: From General to Specific

- How do individual differences of prior knowledge, computer experience, and language background affect children when playing digital educational games?
- What effects do the games have on the students' academic mathematics achievement?
- What effects do the games have on children' motivation?
- What Experts would do to apply help? When?

- What Experts would do to scaffold the tasks? When?

Experts´ Sight

- How would Experts adapt the game individually to children of different ages variying between 4 and 8 years.

- How would Experts recognize the varying states of the player, as he/she performs the game.

- How would Experts judge and estimate player´s actual skills in order to give him the right game situation?

  - if underestimated, beneath his/her skills, Both events and tasks should be scaffolded (more complex and harder). (Boredom & Annoying State)

  - if overestimated, over his/her skills, Both events and tasks should be more basic and easier. (Challenging & motivated State; Confusion & Frustration)

- How would Experts, psychologists, and pedagogues interpret the value of Micro-Adaptivity in our Game?

- When do children loose the interest in the game?

- When would experts/pedagogues/teachers suggest to activate/enable the adaptive mode?

- Which variable and with which amount is responsible for and how to maintain the challeges in Game continuous?

  - longer Gameplay & Enjoyment

  - Success in Tasks ()

  - Better Skill Acquisition

Developers´ Sight

- As
  "Bad games have little challenge, or too much challenge. Good games have just the right amount." - [162];
  How would we, by means of Adaptivity, adjust the challenge in the Game within the Game flow Corridor?

- How would we ensure an individual and continuous Gameplay through the Flow Channel?

- How would we vary the adaptive variables, without annoying children or without affecting both Gameplay and Challenge?

- When should we activate the adaptive mode? (To define after observation)

- Which variable should we adjust and how much?

- What are the difficulties in the given game example, and how they relate to different skills necessary in the game?

We enlisted the help of several different kinds of experts to acquire and set up the settings for the adaptive mode that assure a reasonnable amount of difficulty and motivation in the Game.

Such interviews might not be high on a hierarchy designed to determine objectively the effects of the intervention of Adaptivity, but would be high on a hierarchy designed for generating in-depth insights about children's perceptions, feelings and attitudes.

7.2.2 *Interview Results*

In the first interviews we explicitly asked abstract questions to the experts, and did not go into detail regarding our game, in order to build us a whole idea, how experts handle the pedagogical and psychological aspects of serious games and for eventually provident help.

In the next step we focused on our game especially:

1. to identify the game elements and learning content that are related to adaptivity.

EVENTS
Task Event • Squashing bad bugs • Saving good bugs
Game Event • Good or bad bug escaped • Good or bad bug squashed • Bad bug doubled • Good bug eaten • Good or bad Bug entering

Table 2: Events in Bug Game

2. to differentiate between learning content and game elements.

3. to find reasonable different difficulty states.

4. to identify necessary skills required to attain the goals of the game.

5. to relate these skills to events and tasks in the game, where they can be learned from.

A variety of events can take place during the process of the game as declared in Table 2 on page 67.

Some of them are system autonomous and the others rely on the activity of the player.

The study provided detailed description of tasks and events that can be adapted.

We specified six elements which could be adaptable:

ADAPTABLE VARIABLES	ADAPTABLE PROPERTIES
Number Sign	{1, 2}
Bugs	{Art, Speed, Color}
Entrance of bugs	{Time Intervall, Percentage of Good/Bad}
Digits on bugs	{Dice-like, Random}
Encounter of bad bugs	Duplicate {yes, no}
Escape of bad bugs	Exit {yes, no}

Table 3: Adaptable variables & their properties in Bug Game

- The quantity of number-signs held by Emil and Pauline, which indicate good bugs, can vary between one and two.
- The bugs can be adjusted in regard to their speed and color.
- The consequence of two bad bugs hitting each other is either none or they multiply.
- Whether bad bugs can leave the cave on their own.
- Which bug is to appear.
- The amount of bugs currently on the screen, and the percentage of good and bad bugs currently entering.
- The digits on bugs can be either arranged as they are on a dice or have a random arrangement.

The following variables, Table 3 on page 68, can be applied independently and customized, to meet the individual child's standard.

Further we identified four game situations with various difficulties, which are age derived. These, in the traditional jargon of games, called levels, could be easily switched to easier or harder mode, as the player needs.

- **Level 1 (for 3-5 years)**
  - Number-sign: One good number
  - Encounter of bad bugs: no multiplication
  - Escape of bad bugs: no autonomous escape
  - Bugs: all have the same speed (slow); good bugs are green, bad bugs are red
  - Appearance of bugs: maximum of five bugs on the screen; equal amount of good and bad bugs appear
  - Digits on bugs: dice-like
- **Level 2 (for 4-6 years) or LevelUp**
  - Number-sign: One good number
  - Encounter of bad bugs: no multiplication Escape of bad bugs: no autonomous escape
  - Fireflies: all have the same speed (slow); random color
  - Appearance of bugs: maximum of five bugs on the screen; equal amount of good and bad bugs appear
  - Digits on bugs: dice-like
- **Level 3 (for 5-7 years) or LevelUp**
  - Number-sign: two good numbers
  - Encounter of bad bugs: multiplication
  - Escape of bad bugs: autonomous escape bugs: bugs with higher numbers are faster; random color

  - Appearance of bugs: maximum of eight bugs on the screen; equal amount of good and bad bugs appear

  - Digits on bugs: dice-like

- **Level 4 (for 6-8 years) or LevelUp**

  - Number-sign: two good numbers

  - Encounter of bad bugs: multiplication

  - Escape of bad bugs: autonomous escape

  - Fireflies: all bugs are faster; bugs with higher numbers are faster; random color

  - Appearance of bugs: maximum of eight bugs on the screen; more bad bugs

  - Digits on bugs: random

Assuming that the tutor characterizes the learner by recognizing her / his skills, we identified the skills required for all scenarios of the game and differentiate between those related to the game elemets and those related to the learning content as shown on Table 4 on page 71.

Some of the Adapt Events manipulate and influence the difficulty of Learning Content Aspects others the difficulty of Game Aspects as shown on Table 5 on page 71.

To summerize the results:

We now have data concerning the difficulty of the learning content and game elements.
There are game elements that need to be adapted, to make the game easier or harder.
Some of them are related to the learning content, and other not.
The learning content is segmented in task-sets.
Each set has a skill associated to it.

One of the conclusions we drawed here is that the game elements in form of adaptable properties can be used to increase or decrease difficulty and that they affect some skills when the difficulty is changed.

SKILLS
Learning Content Skills • Recognizing {(dots in order), (dots without order)} • Counting {(dots in order), (dots without order)}
Game Aspect Skills • Squashing bad bugs {(to limitate collisions & duplications), (to avoid bad bugs exit)} • Saving good bugs {(by moving toward exit)}

Table 4: Learning Content vs. Game Aspect Skills in Bug Game

ADAPT EVENTS	INFLUENCE ON
Set quantity of number-signs	LCA
Set encounter of bad bugs	GA
Set escape of bad bugs	GA
Set speed of bugs	LCA & GA
Set color of bugs	LCA
Set number of bugs on screen	LCA & GA
Set percentage of good/bad bugs on screen	GA
Set order of digits	LCA

Table 5: Adapt Events & their influence on the game process in Bug Game

This can be used to make the same task more difficult for experienced players.

7.3 OBSERVATION

7.3.1 *Tricky Emotions*

Fostering emotional literacy in young children is the next complex task

When observing children, we may encounter difficulty, trying to understand children´s emotions.

There are many factors that impact our ability to understand children´s emotions like the body language, the tone of voice, the facial expressions and the psychological responses (laughing, ...).

The ability of labeling emotions consists in identifying (Which emotions do the following faces express?), understanding (How do you know?) and responding to them in a healthy manner and this is hard to manage because:

- all emotions are valid; it is how we interpret them that counts,
- emotions may change through the experiment,
- children can have more than one emotion about the game state, and
- we can feel differently than someone else about the same emotion.

Let we consider the Figure 12 on page 73;

We could identify 6 principle states of emotions in young age going from:

- happy
- sad
- embarrassed
- scared
- nervous

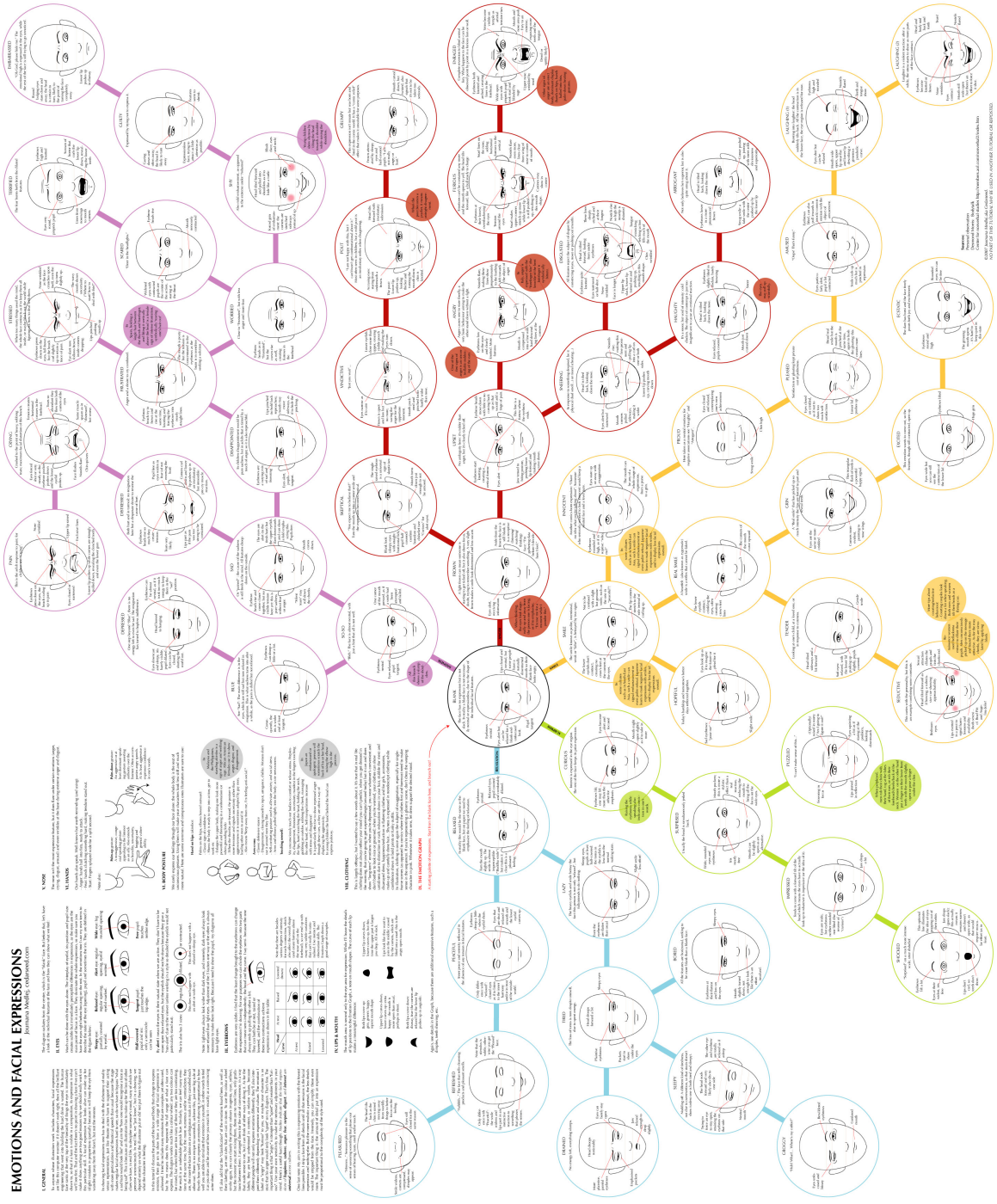


Figure 12: Emotions & Facial Expressions - Google

- mad

and for each state we could identify the corresponding facial expressions and the clues that experience that:

- Happy - smiling
- Sad - frowning
- Embarrassed - cheeks, lips, eyes rolled
- Scared - mouth opened, eyes wide
- Nervous - sweating, teeth, eyebrows
- Mad - tight mouth, eyebrows

7.3.2 *Results*

The observation gave us, but especially, experts ideas, how children are doing with the game situations they proposed.

Deeper we identified:

1. if they are age adequate?
2. Where do they have problems understanding the game or game elemets?
3. the average time taken per level?

7.3.2.1 *Bug Game: Game Situations*

As suggested from experts, we made some changes to the game and built the proposed Game Situations as mapped [EASY] Table 6 on page 76, [MEDIUM] Table 7 on page 77, [DIFFICULT]Table 8 on page 78 and [ADVANCED] Table 9 on page 79, with diffrent values affecting both game and learning elements to attain the maximum of challenge in the game.

Due to the small screen of the iPad, we were forced to keep some variables non-adaptive, even predefined namely:

- Bugs on the screen (no more as 8)
- New bugs entering (no more as 4)
- Maximum Duplication of bad bugs (Limit to 8)

Claims have been done about the correlation between adaptive variables, so freely isn´t it?

- The factor Duplication, factor Speed and factor Collision correlate together;
  So if we adjust one of them, we should be aware of the others, in order to mainatain the flow.
- If we differentiate the color of bugs, the speed should be relatively higher.

These considerations have been concluded and taken in consideration for future work.

7.3.2.2 *What Claims can be observed from the impact of game adaptation*

Although we differentiated first between game and learning elements, while building the game situations we played with both as a whole.

The first observations were difficult, since children, some of them, have not understood the goal of the game.

We observed that:

- Some only squash bad bugs (They enjoyed that, since it was an easy task).
- Others, who understood the learning task, concentrated only on saving good bugs, neglected the squash task (They were rapidly annoyed, since bad bugs duplicated and heva eaten good bugs).
- Others needed help to differentiate between good and bad bugs and enjoyed only the first Game Situations.

ADAPTIVE VARIABLES	VALUE
Number of Bugs (Non-Adaptive)	60
Good/Bad Ratio (goodBugsRatio)	0.7
Entering Rate ()	7
Speed Rate (Speedfactor)	0.75
Speed Bugs (isAdvanced_Speed)	NO
Collision - Duplication (isAdvanced_BadBugsDuplicate)	NO
Entering Bugs: 4 (PREDEFINED Small iPad Screen)	4
maxLimitEntrance: 8 (PREDEFINED Small iPad Screen)	8
maxLimitDuplication: 8 (PREDEFINED Small iPad Screen)	8
Color (isAdvanced_NumbersOnly)	YES
Exit (isAdvanced_BadBugsExit)	NO
Random	NO
Target Numbers (E&P)	NO
OnlyOneTarget	YES

Table 6: Game Situation 1 (3-5 years); Starter Level

ADAPTIVE VARIABLES	VALUE
Number of Bugs (Non-Adaptive)	60
Good/Bad Ratio (goodBugsRatio)	0.6
Entering Rate ()	6
Speed Rate (Speedfactor)	1
Speed Bugs (isAdvanced_Speed)	YES
Collision - Duplication (isAdvanced_BadBugsDuplicate)	NO
Entering Bugs: 4 (PREDEFINED Small iPad Screen)	4
maxLimitEntrance: 8 (PREDEFINED Small iPad Screen)	8
maxLimitDuplication: 8 (PREDEFINED Small iPad Screen)	8
Color (isAdvanced_NumbersOnly)	NO
Exit (isAdvanced_BadBugsExit)	NO
Random	NO
Target Numbers (E&P)	NO
OnlyOneTarget	NO

Table 7: Game Situation 2 (4-6 years)

ADAPTIVE VARIABLES	VALUE
Number of Bugs (Non-Adaptive)	60
Good/Bad Ratio (goodBugsRatio)	0.5
Entering Rate ()	5
Speed Rate (Speedfactor)	1
Speed Bugs (isAdvanced_Speed)	YES
Collision - Duplication (isAdvanced_BadBugsDuplicate)	YES
Entering Bugs: 4 (PREDEFINED Small iPad Screen)	4
maxLimitEntrance: 8 (PREDEFINED Small iPad Screen)	8
maxLimitDuplication: 8 (PREDEFINED Small iPad Screen)	8
Color (isAdvanced_NumbersOnly)	NO
Exit (isAdvanced_BadBugsExit)	NO
Random	YES
Target Numbers (E&P)	YES
OnlyOneTarget	NO

Table 8: Game Situation 3 (5-7 years)

ADAPTIVE VARIABLES	VALUE
Number of Bugs (Non-Adaptive)	60
Good/Bad Ratio (goodBugsRatio)	0.4
Entering Rate ()	4
Speed Rate (Speedfactor)	1
Speed Bugs (isAdvanced_Speed)	YES
Collision - Duplication (isAdvanced_BadBugsDuplicate)	YES
Entering Bugs: 4 (PREDEFINED Small iPad Screen)	4
maxLimitEntrance: 8 (PREDEFINED Small iPad Screen)	8
maxLimitDuplication: 8 (PREDEFINED Small iPad Screen)	8
Color (isAdvanced_NumbersOnly)	NO
Exit (isAdvanced_BadBugsExit)	YES
Random	YES
Target Numbers (E&P)	YES
OnlyOneTarget	NO

Table 9: Game Situation 4 (6-8 years)

The interaction between game and learning elements has shown that, if coherent, this produces the most of the gaming experiencce and let children immersed, since they enjoy gameplay.

Experts rebuked us to use also appropriate audio feedback and to build a new-gamer-tutorial to guide the new player through the game story.

8 DISCUSSION

8.1 SCIENTIFIC EVIDENCE

The scientific evidence stems from the ZPD and Flow theories combined together.

The Learner ZPD Evaluator model is constructed based on the ZPD theory as shown on Figure 13 on page 82.

Performing a hard or simple task with inadequately developed skills or with high-order skills pushs the learner accordingly either in the zone of confusion or in the zone of boredom and automatically neglect efficient learning.

Through the Trial&Error principle or with adequate pedagogical support, the learner could increase his skill level himself and so perform the task easier.

If the learner lies in the zone of boredom, the system should be able to shift him back to the ZPD zone, by adapting the game and/or learning elements to a more challenging and motivational state.

8.2 RESTATEMENT OF THE RESEARCH QUESTION

The intention from this evaluation is neither to gather data such as video material or experts interviews for further analysis with statistical analysis software nor to develop charts mentioning the success of the developed game.

The intention, due to the evaluation period during implementation, is to develop theories from the hypotheses that describe the impact of the adaptive mode.

Keeping in mind the theories of Gameplay, Learning through play, Game Flow, Learning through Try&Error, Vygotsky's theories of individual ZPD & Scaffolding;

If we would adapt, we should be aware of all of these theories, better said, we would adapt individually to the needs of the player playing

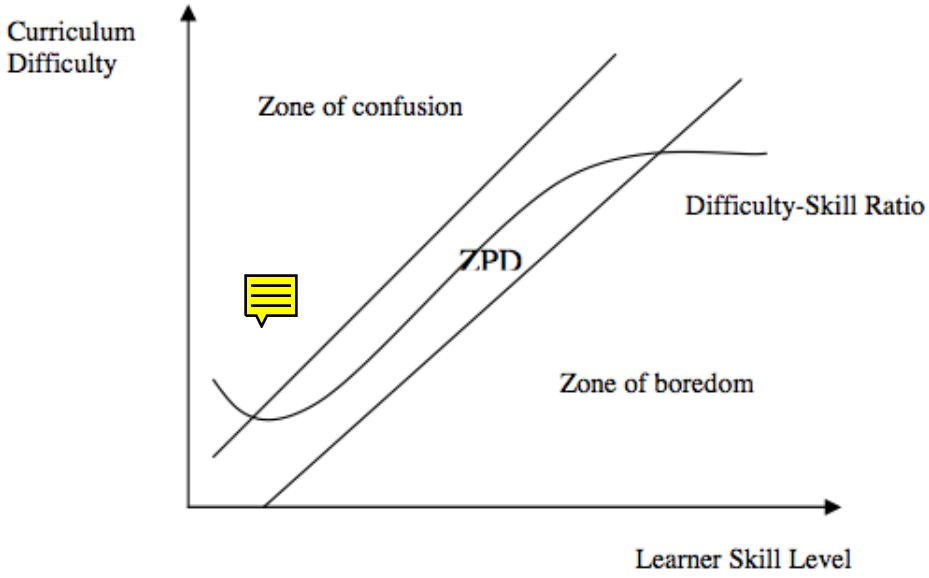


Figure 13: Difficulty-Skill Ratio (ZPD Theory) - [206]

the game at the moment.

In this scope would Adaptivity play an innovative and efficient role while accompaining the player through his gaming experience, keeping him out of the routine and frustration states, letting him immersed in the game and so producing the best learning outcome.

8.3 SUMMARY THAT SYSTEMATICALLY ANSWER YOUR RESEARCH QUESTIONS

Experts´ interviews acted as validating instrument for the pedagogical patterns in the game.

These were than deepenend by in-field obseravation to approach the issues of reliability and validity.

The explanation of the phenomena constructed the "justified true belief'", which is the perceived knowledge which supports the foundation of the conclusions of this research.

This evaluation ensured the validity of the pedagogical reasoner module to define general and variable-specific rules that would garantie a continuous and immersed gameplay within th optimal adaptivity corridor as shown on Figure 14 on page 83.

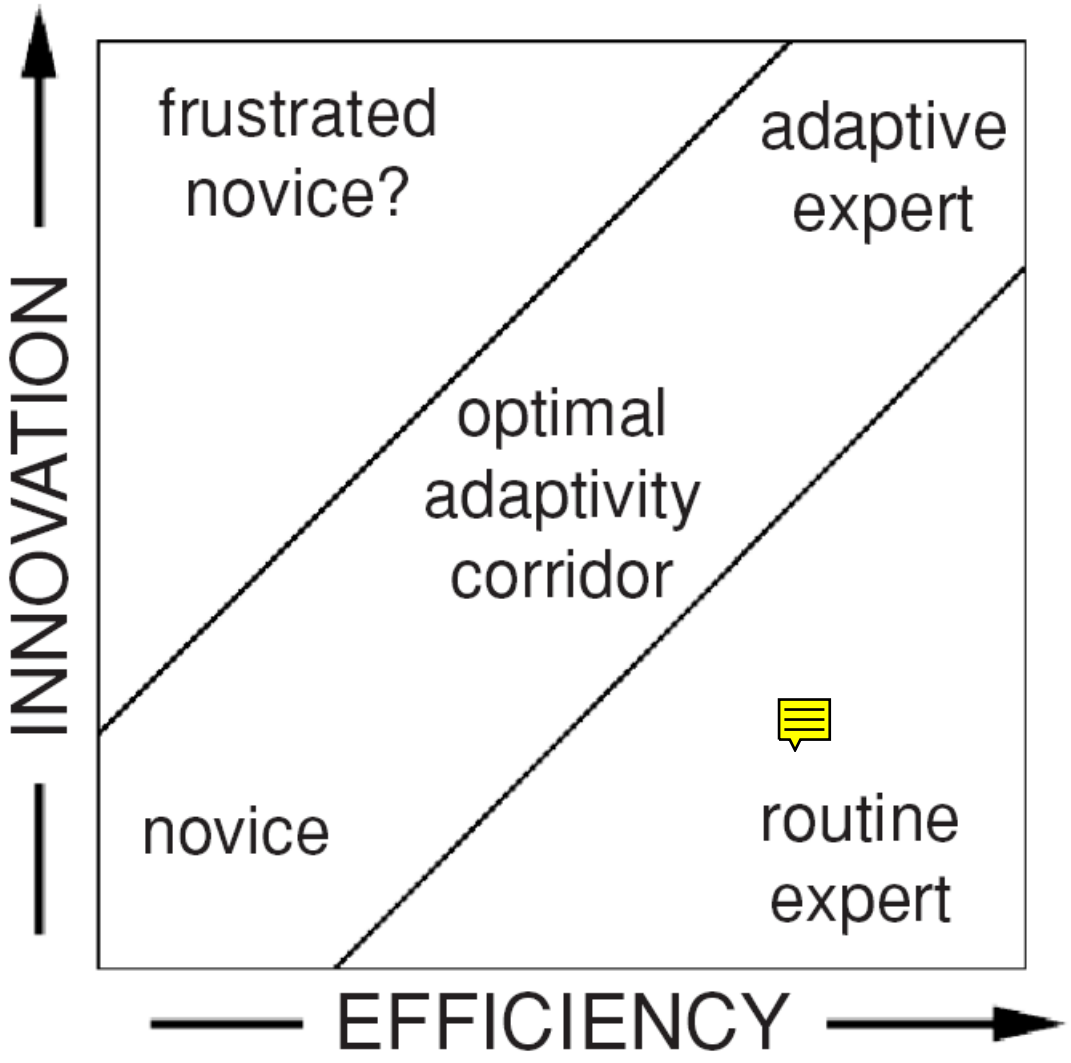


Figure 14: Combining the Flow, ZPD & Scaffolding Theories to define the Optimal Adaptivity Corridor

8.4 CONCLUSION

If we adapt, we should be aware of the Game Flow, we should adapt individually, with just the right amount and responding to the actual needs of the player.

Making the Events and the Tasks more complex would motivate and encourage the child, otherwise, if too hard, that would interrupt the gamplay and annoy the child.

8.4.1 *Contribution*

Serious Games Researchers are starting to realize that integrating assessments into gaming environments is important and that external multiple-choice questionnaires and human-scored artifacts are not sufficient to assess all that people may be learning in games, since the latter are time-wise inefficient and do not scale easily.

Kickmeier-rust et al. [95] affirm that:

> Considering the importance of not destroying immersion with the game, the assessment of the learning progress and psycho-pedagogical feedback must occur in a non-invasive way. This requires an intelligent system that is capable of assessing individual competencies and learning progress by observing and interpreting behaviour within the game.

Underwood et al. [189][1] ensure that:

> The time is ripe to create educational gaming environments since technology is now available to integrate assessments and implement data collection and adaptivity in near real-time. We have developed a set of capabilities to design and integrate assessments into games, visualize and analyze data, and individually adapt games. Additionally, we are continuing to research and develop methods for making inferences about behavior and learning in gaming environments. Embedded assessments that are truly integrated into the design of the game provide learners with the opportunity to immediately learn from their mistakes. In order to take advantage of this idea, we must design games to integrate opportunities for learners to display the skills they are intended to learn, allowing the learner to enjoy and experiment with trial and error without interrupting gameplay.

1 (http://www.pr-sol.com/)

Chen and Michael [23] reassure that:

> Because serious games have not yet been shown to be effective (Federation of American Scientists, 2006), the adoption in education of games is slow, regardless their engaging approaches to learning. One way to show they are effective is to measure the learning that occurs during play.

As recommended from serious games researchers of the last decade, 21st century serious games will rely on in-game data and sense made of this data — No small task to be sure —, to enable the dynamic delivery of new, individualized information and activity into the game.

Incorporating assessment systems into serious games would track learner/player behavior over time, validate game objectives and improve individual success.

The result is an improvement in overall engagement and educational impact for the individual learner and clearer snapshot of game impact for the development team.

8.4.2 *Consideration for Bug Game*

From a technical point of view, the major challenge is first to merge gaming and learning methodologies and technologies, second to develop high quality educational games in order to meet the high expectations of learners in terms of quality in graphics, sound, gameplay and pedagogical and didactic aspects.

In this game it might be additionally interesting to monitor which bugs the actions are being performed with?

Whether the child is reacting equally to each number or for example prefers simple numbers like one or two;

Or whether a child is only reacting to numbers that have a bigger difference to each other (e.g. if the good bugs are those with three dots on their back: Is he/she only squashing bad bugs with one or six dots, because they are easier to distinguish? That might indicate that he / she is using recognition rather than counting.).

The Game Events correlate with the Task Events.

Some are directly induced by a Task Event, others are consequential.

A high amount of good bugs eaten and bad bugs escaped by chance will show a negative correlation with the number of bugs squashed.

A high amount of good bugs escaped by chance will show a positive correlation.

We experimented with few samples of children, have defined general game situations settings that would ensure the game flow depending on the right association skill level and child/gamer;

But even if the game situation at the moment presents a suitable difficulty for the child playing it, after some hours enjoying the game, it would be annoying, if we don´t switch to another game situation more complex;

The question here is when should we switch?
Should we make it more difficult or more easier?
Depending on who´s playing? What skills does he / she have?
How would we switch individually?

As a result from the experts´interviews and interpretation of the recorded observational material helped us to develop a preliminary theory of adaptive factors affecting user satisfaction, their correlation with each others and their impact on children´s motivation and achievement.

These two factors have benn analyzed as dependent variables, effects and auto-reaction to the stimulus of adaptivity

As we would, in the future, track the player over time, some changes related to the Game Log should be conducted.

- Score: Until this evaluation time, the score was calculated only by means of saved good bugs;
  This is not enough, if we would track the actions of the player all the time.
  We would adopt the new score calculation on the basis of this
  - [+1 if good bug saved]
  - [-1 if bad bug exits]
  - [-2 if bad bugs doubled]

- Time: the time for a game session of 60 bugs, after observation of 10 children, have been averaged to 3 minutes.
  This should be integrated in the score. For players who spend more than 3 minutes, the score should decrease every 30 seconds.

Therfore three additional variables should be added into the system.

These will be, in addition to the score calculation, responsable for a better interpretation of the activity of the player.

- Eat Quote: to identify, if the player really plays, and squashs the bag bugs;

- Exit Quote: to idetify, if bad bugs exit;

- Squash Quote: to interpret the interactivity of the player and his reaction speed;

8.5 RECOMMENDATION FOR FUTURE RESEARCH

Evaluation of the Real-Time adaption mechanism in DEG's.

As a recommendation for future evaluation and in order to let experts interact live with the players into the game although without interrupting or letting the gamer feel that some one is changing the game artefacts while he / she plays, we imagined a test solution, called "RemoteEqualizerTool", shown on Figure 15 on page 88, consisting of two iPads, facilitating us the remote control of the adaptive variables wirelessly while playing.

The interest relies in tasks that have been characterized as "Remote Help Giving" (Tolmie et al., 2004) or "Remote Scaffolding" (Taha, 2012) where one of the collaborators has the task knowledge and one of the collaborators manipulates the task artefacts.

As far as is known that:

"Learning is often characterized in terms of the relationship between Instructor and Learner with the Instructor either passing on knowledge or creating an environment for the Learner that is rich for self-discovery (e.g. Vygotsky's zone of proximal development, Vygotsky, 1978; Bransford et al., 2000)." - [97]

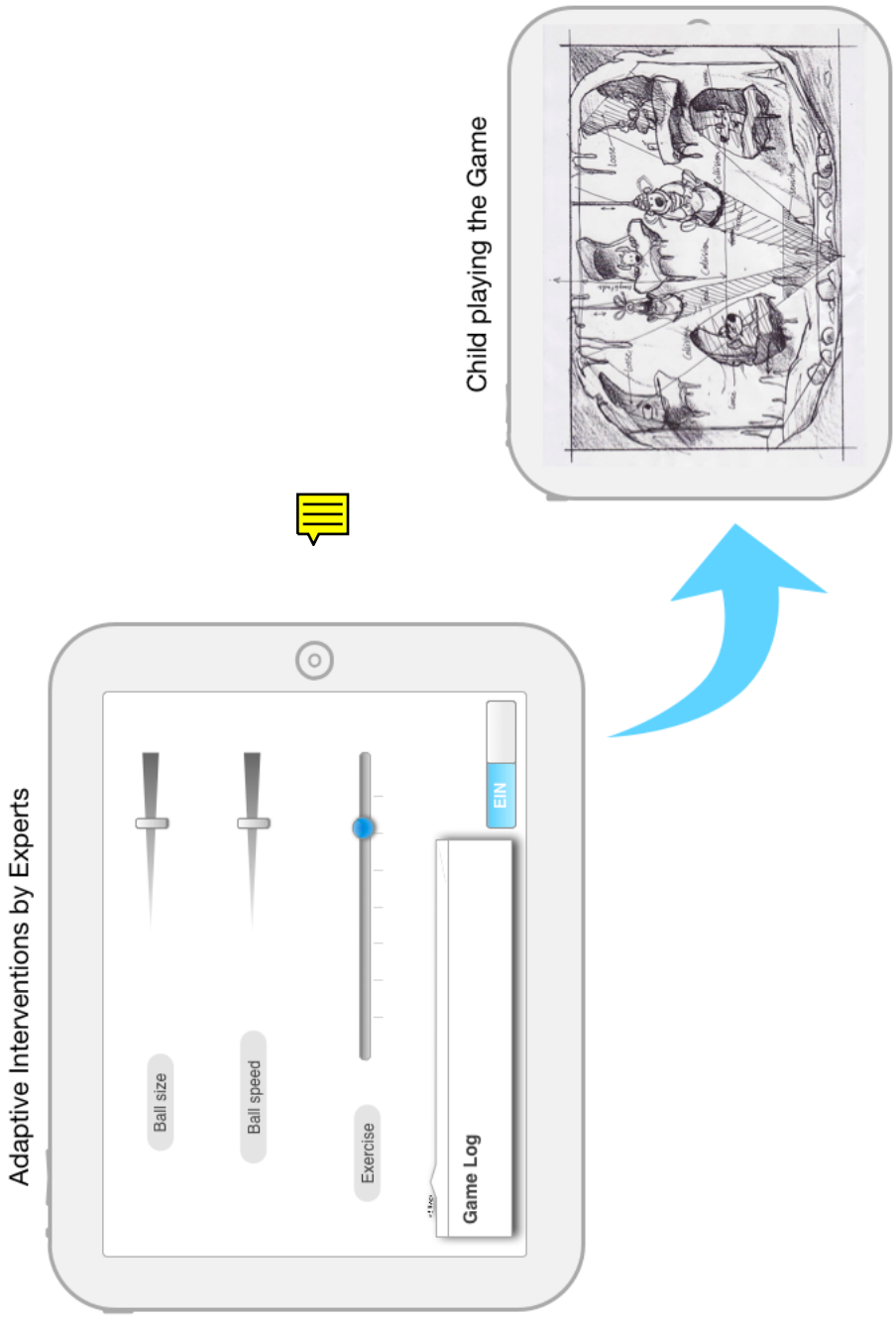


Figure 15: Remote Equalizer Tool

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.

Part V

APPENDIX

A

APPENDIX

A.1 VIDEO MATERIAL PERMISSION

Our study would be videotaped, since we rely on the experts´ interpretation. Therefor participants have been told that:

- the play sessions will be videotaped;
- the cassettes will be coded so that no personally identifying information is visible on them;
- they will be kept in a secure place (Chair for Applied Software Engineering, TUM);
- they will be viewed only for research purposes;
- they will be erased after they are transcribed or coded.

Betr.: Spielerisches Lernen mit dem iPad / iPod
Hier : Möglichkeit der Teilnahme und Einverständniserklärung

Sehr geehrte Eltern,

Die Technische Universität München führt derzeit das Projekt “Spielerisches Lernen mit dem iPad” durch, welches den Zusammenhang von Spielen und Lernen im Kindergarten/Vorschulalter (und 1. Klasse) untersucht.

In verschiedenen Untersuchungen wurde bereits gezeigt dass “ernste” Spiele im Vorschulalter das Lernen positiv beeinflussen und ausserdem **sehr viel Spass machen**. Ernste Spiele, sind ganz normale Spiele bei denen etwas sinnvolles gelernt wird.

Die Technische Universität München möchte mit einem ernsten Spiel untersuchen, wie Kinder im Kindergarten und in der Vorschule (und in der 1. Klasse) Mathe lernen.

Dabei sollen die Kinder nur eine kurze Zeit auf dem iPad spielen.

Wenn es ihnen Spass macht und sie Lust dazu haben können sie auch ein paar Fragen beantworten.

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Technische Universität München

Datenschutz

Es werden nur von den Schülern Daten erhoben, deren Eltern ihr Einverständnis schriftlich erklärt haben. Daher möchten wir Sie bitten, die folgende Seite auszufüllen

Die Teilnahme ist freiwillig. **Sie können Ihre Zusage jederzeit und ohne Angabe von Gründen zurückziehen.** Die Daten werden selbstverständlich anonymisiert und nicht an Dritte oder für andere Zwecke weitergegeben.

Wir freuen uns, unsere Forschung für Kinder mit Ihrer Unterstützung durchführen zu können. Bei Rückfragen oder weiterem Informationsbedarf können Sie uns gerne kontaktieren.

Mit freundlichen Grüßen,

Damir Ismailović

damir.ismailovic@in.tum.de

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Details zu dem Spiel

Liebe Eltern,

Im Rahmen des iOS-Praktikums erstellen wir in Kooperation mit dem United Soft Media Verlag (USM) ein Lernspiel auf dem iPad. Um bereits im Vorfeld erste Einblicke zu erhalten, wie Kinder mit dem iPad interagieren, würden wir diesen gerne beim Spielen ein paar Minuten über die Schulter schauen. Dabei fragen wir lediglich nach dem Alter des Kindes, erfassen darüber hinaus aber keinerlei persönliche Daten.

Emil und Pauline – Reihe

Das Lernspiel soll ein weiterer Teil der Emil und Pauline Reihe werden, mit einem neuen Konzept, das speziell auf das iPad zugeschnitten ist. Es richtet sich insbesondere an Grundschulkinder 1. Klasse und Vorschulkinder und bringt diese erstmals mit der Mathematik in Verbindung.

Einige der Spiele aus der Spielreihe können Sie hier online kostenlos ausprobieren auf http://www.emil-und-pauline.de/online-spielen.html

Die Spielereihe ist sehr erfolgreich und wurde in der Vergangenheit mehrfach preisgekrönt.

Es würde uns freuen, wenn Sie uns helfen, die hohe Qualität aufrecht zu erhalten.

Mit freundlichen Grüßen,

xxx

Wenn Sie möchten informieren wir Sie natürlich gerne auch weiterhin über das Projekt. Geben Sie dazu einfach Ihre Email-adresse an: .....

Mit freundlichen Grüßen,

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Technische Universität München

Einverständniserklärung
zur Teilnahme an dem Projekt „Spielerisch lernen mit dem iPad / iPod“

Hiermit erkläre ich,

_____ , geb. am _____
Name eines Erziehungsberechtigten — Geburtsdatum

_____ , geb. am _____
Name des Teilnehmers / der Teilnehmerin — Geburtsdatum

_____ ; Telefon: _____
Anschrift

_____
Email-Adresse

dass ich die mir vorgelegte Elterninformation verstanden und eine Kopie dieser Information und meiner Einwilligung erhalten habe.

Ich erkläre mich mit der Teilnahme meines Kindes an dem Projekt zum Thema „Spielerisch lernen mit dem iPad “ einverstanden.

Ich bin darüber informiert worden, dass die erhobenen Daten nach einer Verschlüsselung mit einem Code elektronisch gespeichert und zum Zwecke der wissenschaftlichen Auswertung verarbeitet werden. Eine Weitergabe dieser Daten erfolgt nur zu Zwecken der Studie und nur in verschlüsselter Form. Die Bestimmungen des Bundesdatenschutzgesetzes werden beachtet. Die erhobenen Daten werden ausschließlich zu den genannten Untersuchungszwecken verwendet. Die Codeschlüssel zur Zuordnung der Daten zu den Teilnehmern und die personenbezogenen Daten verbleiben immer beim Versuchsleiter. Die personenbezogenen Daten und die Codeschlüssel werden unmittelbar nach Abschluss der Erhebung und nach der Rückmeldung an die Teilnehmer vernichtet.

Ich bin damit einverstanden, dass die während des Projektes von mir/meinem Kind aufgenommen Fotos/Videos zu Studienzwecken veröffentlicht werden (wenn nicht zutreffend, bitte streichen)

Mir ist bekannt, dass ich oder mein Kind die Einwilligung **jederzeit ohne Angabe von Gründen und ohne nachteilige Folgen zurückziehen kann**. Darüber hinaus kann ich jederzeit die vollständige Löschung der über mein Kind erhobenen Daten verlangen.

_____ _____
Ort, Datum — Unterschrift des Erziehungsberechtigten

_____ _____
Ort, Datum — Unterschrift des wissenschaftlichen Mitarbeiters

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A.2 OBSERVATION SCREENSHOTS

Figure 16 on the facing page shows us the Eat Animation (5 goob bugs & 3 bad bugs).

Figure 17 on page 100 exposes us an observed state where children missunderstood the task and focused only on saving good bugs and neglected the Sqush task which should be enough engaging through the animations, this event brings with.

Figure 18 on page 101 points out the Duplication Event, where two bad bugs collide, they duplicate and become four bad bugs.

This should motivate the player to squash them flat.

Figure 19 on page 102 displays the Exit event, when good bugs are being saved and throwed through the exit, or when bad bugs escape.

Figure 20 on page 103 exposes us the situation, where the child wasn´t quick enough to save all good bugs or squash all bad bugs.

Figure 21 on page 104 features an advanced gamer, that was stronger than our estimations and played perfect our Advanced Game Situation.

He managed all required tasks quicker than us, developers of the game.

He broked all our first results and led us to further considerations.

Nevertheless, figure 22 on page 105, offers an unexpected situation, a situation that we haven´t observed as often as possible, namely;

A player who squashs only bad “red” bugs.

This doesn´t disregard the fact, that he dismissed the task, and neglected the saving task, which is the concept of the game story (Saving bugs through the exit of the cave).

Finally, figure 23 on page 106, shares a score of 25 saved bugs and at the end of the game there was no more bugs on the screen.

This pointed out at the fact that the number of bugs should be relatively higher than 60, to offer a continuous play.

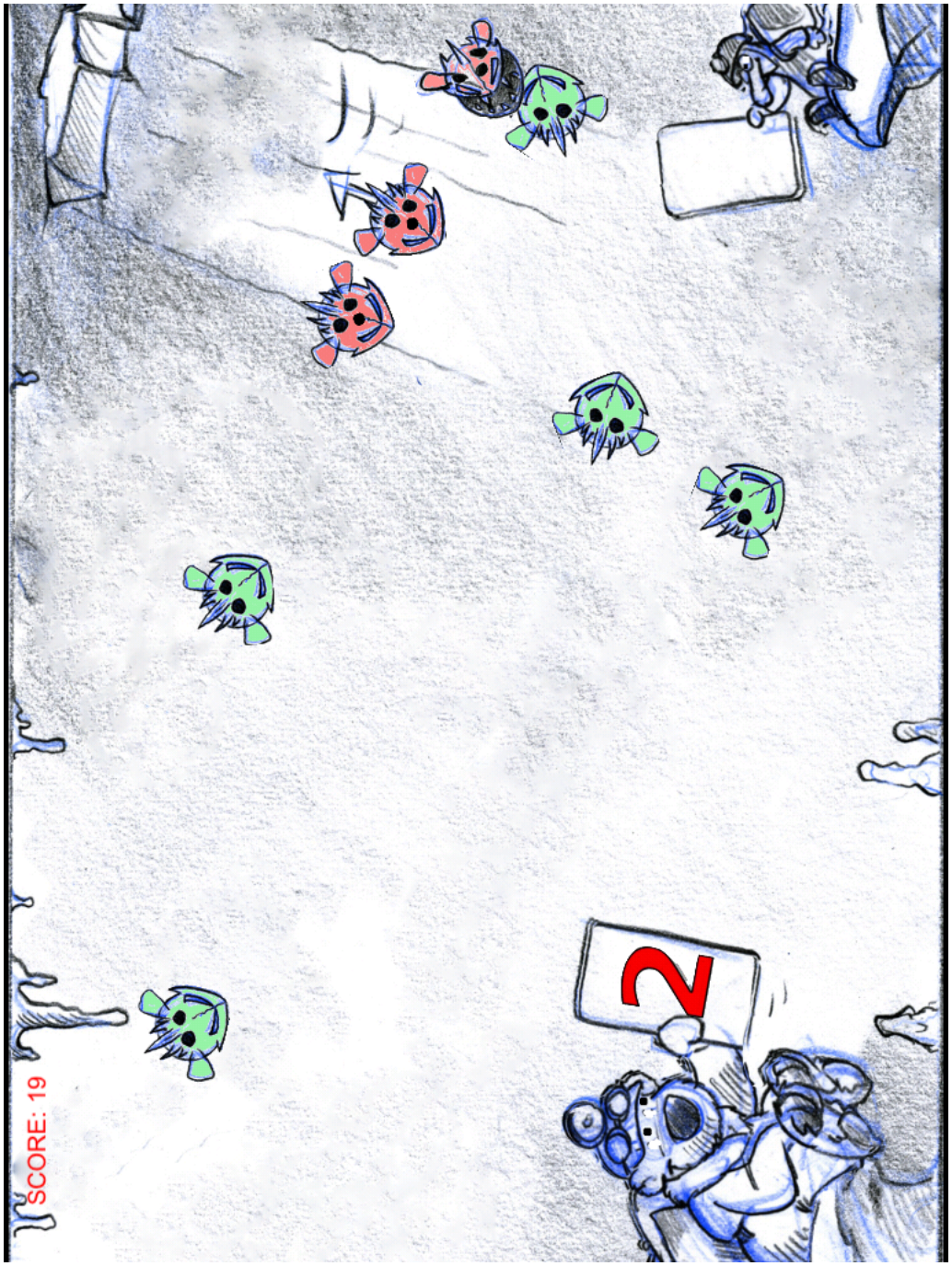

Figure 16: Game State 1

Figure 17: Game State 2

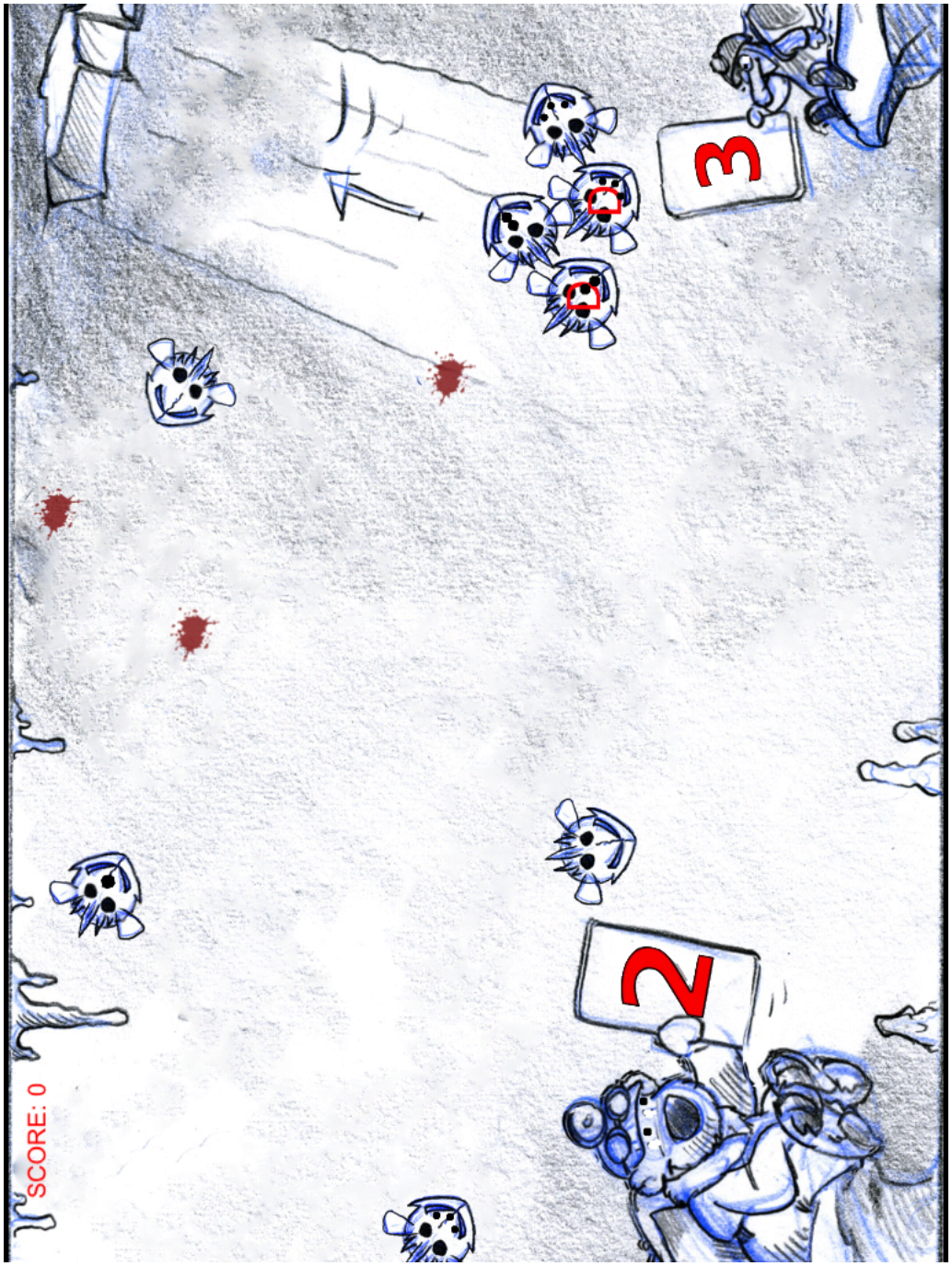

Figure 18: Game State 3

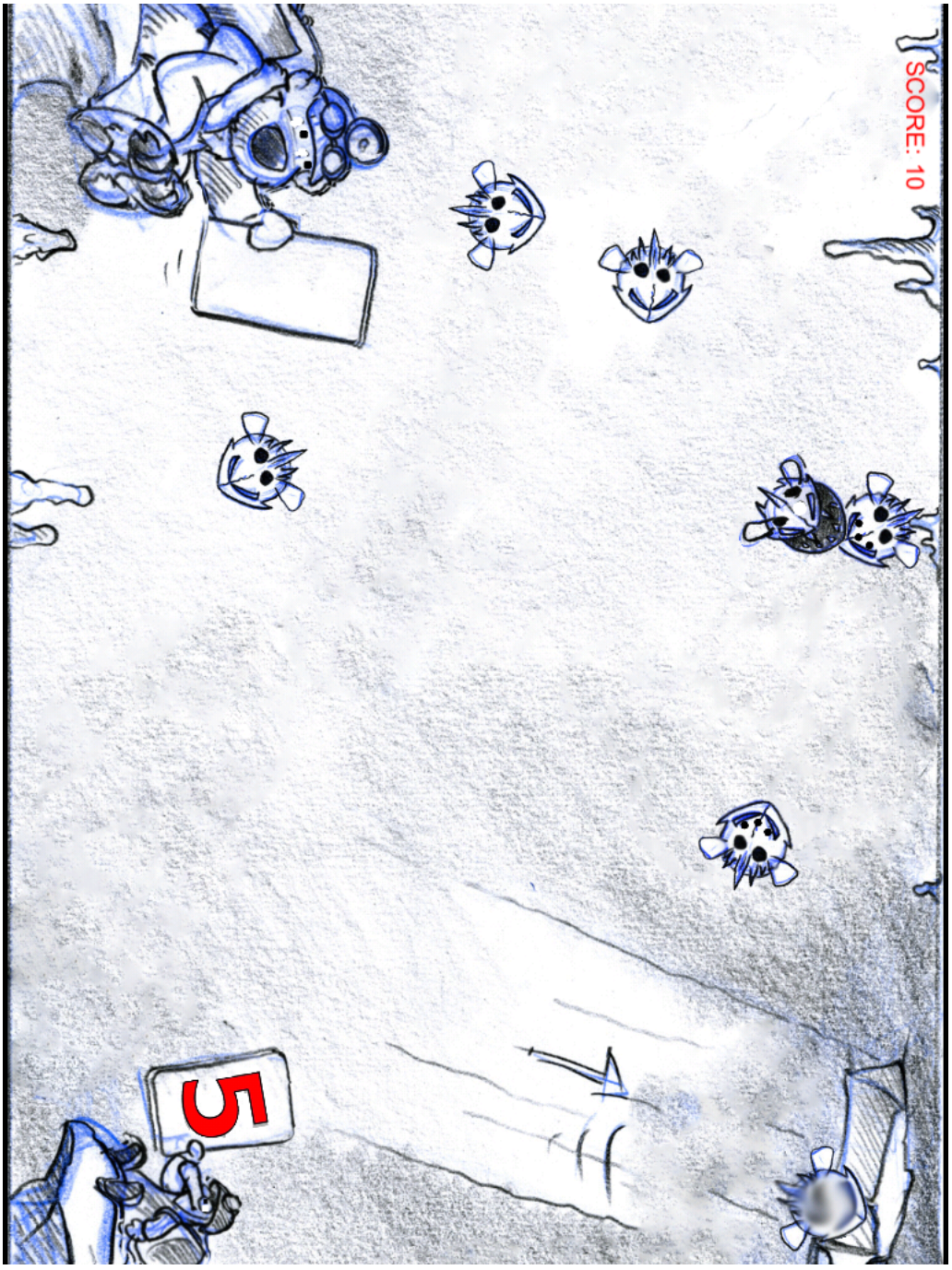

Figure 19: Game State 4

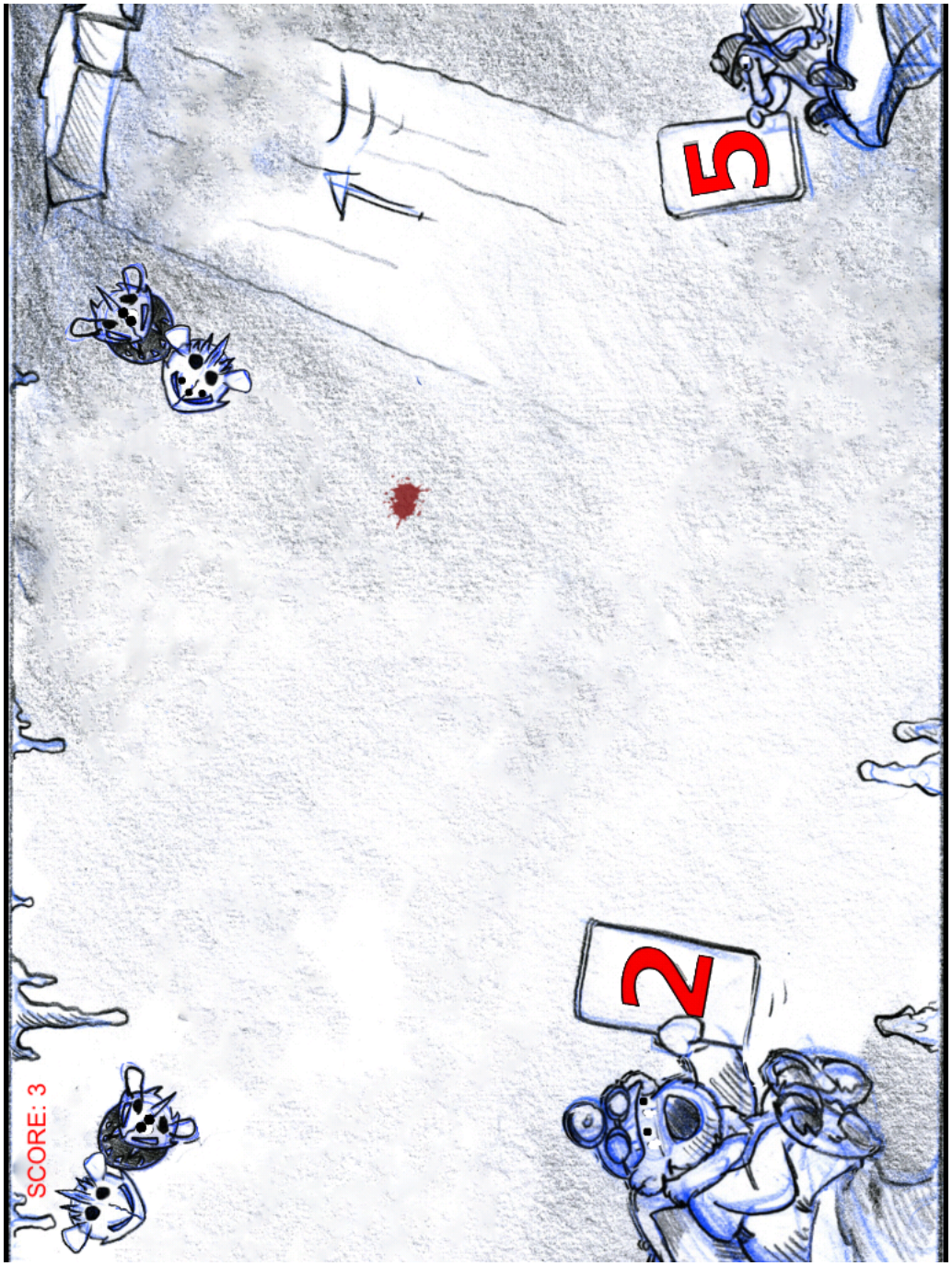

Figure 20: Game State 5

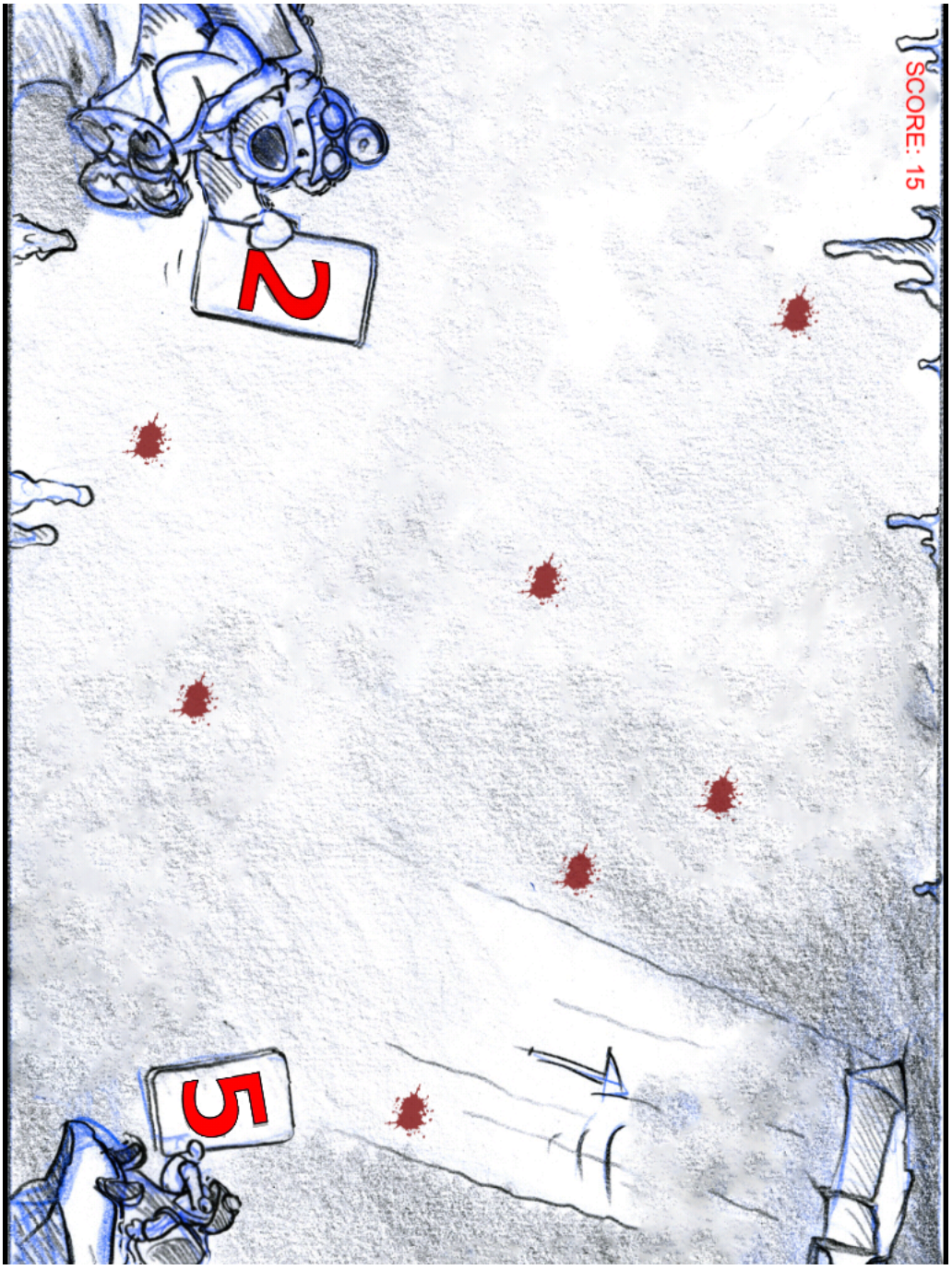

Figure 21: Game State 6

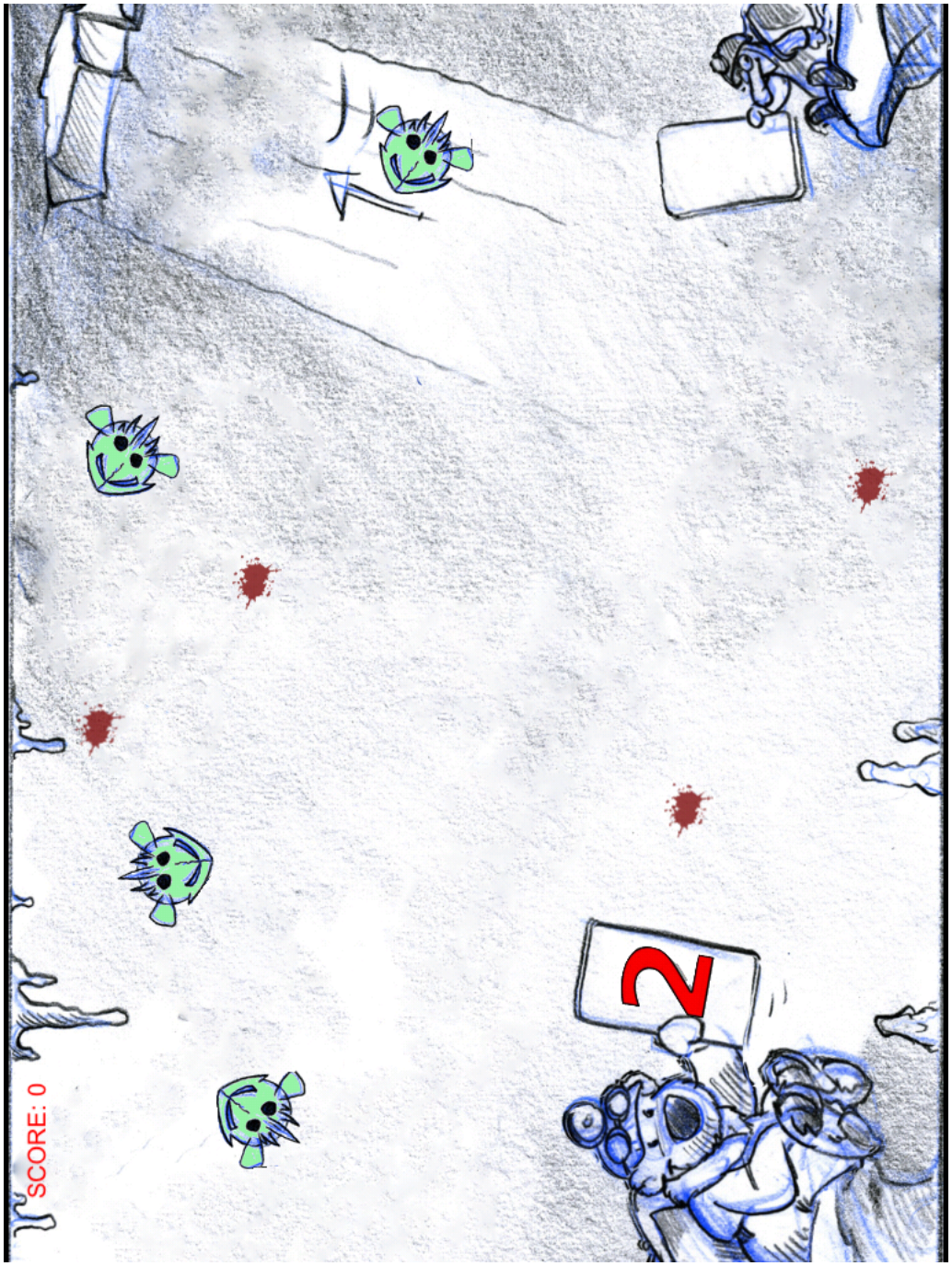

Figure 22: Game State 7

Figure 23: Game State 8

A.3 QUESTIONNAIRE PROTOCOLS

- Did you like the game?
- Was it challenging?
- What was your favorite level?
- Was the game fun?
- Was the game too easy?
- Was the game too hard?
- Was the game easy to learn?
- Are the controls intuitive?
- Is the interface clear and easy to navigate?
- Rate yourself on a scale of one to ten.
- Rate how fun playing was.

The answers may make the game designers feel good and may indicate that the players will at least play the game, but they do not assess the behavioral change that takes place, and they do not tell you that the players have learned from the game.

We used the Questionnaire — already designed by Christina Kold [101] —, actually with the aim of a later formative evaluation, but since we observed, the goal from them was the same.

8 Appendix

8.1 General information questionnaire

General Information			
Interviewer number			
Proband number			
Date			
Age		Gender	

Questions

Question1: Do you have previous experience with electronic games?

1 (none)		**2**		**3**		**4** (a lot)	

(If Q1: 2-4)
Question2: Do you have previous experience with electronic learning games?

1 (none)		**2**		**3**		**4** (a lot)	

(If Q1: 2-4)
Question3: Do you have previous experience with Tablet or Smart Phone Applications?

1 (none)		**2**		**3**		**4** (a lot)	

(If Q3: 2-4)
Question4: Do you have previous experience with iPad Applications?

1 (none)		**2**		**3**		**4** (a lot)	

8.2 Observation protocol[16]

General Information			
Interviewer number			
Proband number			
Date			
Start of game		End of game	

Observations

1. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

2. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

3. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

4. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

[16] It might be necessary to add more pages to the observation protocol, in order to ensure enough tables to record all observations.

5. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

6. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

7. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

8. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

9.State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

10. State Time

1 Boredom	**2** Confusion	**3** Delight	**4** Engagement	**5** Frustration	**6** Surprise	**7** Neutral state

8.3 Questionnaire

General Information

Interviewer number	
Proband number	
Date	

Questions

Question1: Do you like playing computer games or not?

1 (very)		**2**		**3** (undecided)		**4**		**5** (not at all)		**Don't know**	

Question2: How did you like playing this game?

1 (very)		**2**		**3** (undecided)		**4**		**5** (not at all)		**Don't know**	

Question3: How difficult was this game?

1 (very)		**2**		**3** (undecided)		**4**		**5** (not at all)		**Don't know**	

Question4: Would you like to play this game again?

1 (very)		**2**		**3** (undecided)		**4**		**5** (not at all)		**Don't know**	

Question5: Tell me about the good things and the not so good things in this game?

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DECLARATION

I assure the single handed composition of this thesis only supported by declared resources.
Garching bei München, Januar 2012

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